

SCAFFOLDING NOVICES TO LEVERAGE AUDITORY AWARENESS CUES IN FIRST-PERSON SHOOTERS

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ABSTRACT

Today's digital games require the mastery of many different skills. This is accomplished through play itself – sometimes experientially and other times by using explicit guidance provided by the game designer. Multiplayer games, due to their competitive nature, provide fewer opportunities for designers to guide players into mastering particular skills, and so players must learn and master skills experientially. However, when novices compete against better players – as they would if they were new to the game – they can feel overwhelmed by the skill differential. This may hinder the ability of novices to learn experientially, and more importantly, may lead to extended periods of unsatisfying play and missed social play opportunities as they struggle to improve in a competitive context. A game genre that suffers from this problem is the multiplayer first-person shooter (FPS), in which the skill difference between new players and experts who have reached a high level of expertise can be quite large. To succeed in a FPS, players must master a number of skills, the most obvious of which are navigating a complex 3D environment and targeting opponents. To target opponents in a 3D environment, you must also be able to locate them – a skill known as *opponent location awareness*. With the goal of helping novices learn the skill of opponent location awareness, we first conducted an experiment to determine how experts accomplish this important task in multiplayer FPS games. After determining that an understanding of audio cues – and how to leverage them – was critical, we designed and evaluated two systems for introducing this skill of locating opponents through audio cues – an explicit stand-alone training system, and a modified game interface for embedded training. We found that both systems improved accuracy and confidence, but that the explicit training system led to more audio cues being recognized. Our work may help people of disparate skill be able to play together, by scaffolding novices to learn and use a strategy commonly employed by experts.

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CONTENTS

Permission to Use	i
Abstract	ii
Acknowledgements	iii
Contents	iv
List of Tables	vii
List of Figures	viii
List of Abbreviations	xi
1 Introduction	1
1.1 Problem and Motivation	1
1.2 Solution	3
1.3 Steps to the Solution	3
1.4 Evaluation	5
1.5 Contribution	6
1.6 Thesis Outline	7
2 Related Work	9
2.1 Games and Play Experience	9
2.2 Game Balancing	12
2.2.1 Matchmaking	12
2.2.2 Skill Assistance and Difficulty Adjustment	12
2.3 Skills in First-Person Shooter Games	15
2.3.1 The Use of Sound	18
2.3.2 The Use of Strategy	20
2.4 Skill Development and Learning	20
2.4.1 In Games	23
2.4.2 First-Person Shooters Examples	26
3 A System for Evaluating Opponent Location Awareness	27
3.1 Design of the System	27
3.2 Scenarios	32
3.2.1 Game Maps Used	32
3.2.2 Scenario Classifications	32
3.2.3 Scenario Descriptions	33
3.3 Questionnaires	44

3.4	Performance Review	45
3.5	Technical Implementation	47
4	Determining Expert Strategies (Study 1)	49
4.1	Procedure	49
4.2	Participants and Recruitment	49
4.3	Scenarios	50
4.3.1	Data Analyses	51
4.3.2	Individual Scenario Results	51
4.3.3	Grouped Scenario Results	53
4.4	Questionnaire	58
4.4.1	Data Analyses	58
4.4.2	Results	59
4.4.3	The Importance of the Cues	60
4.5	Summary	61
5	Scaffolding Systems	63
5.1	Modified In-Game Interface	63
5.2	Training System	65
6	Helping Novices Leverage Audio Cues (Study 2)	69
6.1	Procedure	69
6.2	Participants and Recruitment	70
6.3	Evaluating the Two Scaffolding Approaches	72
6.3.1	Scenario Groups	72
6.3.2	Questionnaire	79
6.3.3	Summary	81
6.4	The Efficacy of the Training System	81
6.4.1	Data Analyses	81
6.4.2	Results	82
6.4.3	Summary	83
7	Discussion	84
7.1	Types of Awareness Cues	84
7.2	The Differences Between Our Two Scaffolding Systems	86
7.3	Are Our Systems Actually Instructional Scaffolding?	88
7.4	Retention of the Cues	89
7.5	Facilitating Skill Development with Scaffolding	90
7.6	Scaffolding and Commercial Games	90
7.7	Scaffolding's Impact on Play Experience	93
7.8	Limitations and Future Work	94
8	Conclusion	97
8.1	Summary	97
8.2	Closing Thoughts	98

References	99
A Forms	105
A.1 Consent Form	105

LIST OF TABLES

4.1	Descriptive statistics results for each scenario, compared between self-rated <i>Quake Live</i> expertise. Numbers in brackets indicate standard deviation.	52
4.2	Descriptive statistics results for the scenario groups, compared between self-rated <i>Quake Live</i> expertise. Numbers in brackets indicate standard deviation.	53
4.3	Results for the questionnaire, including the descriptive statistics compared between self-rated <i>Quake Live</i> expertise and the results of the one-way ANOVA. Numbers in brackets indicate standard deviation.	59
4.4	Post-hoc test results for the questionnaire, comparing between self-rated <i>Quake Live</i> expertise.	60
6.1	Descriptive statistic results for Study 2's grouped scenarios.	74
6.2	Results of statistical tests for Study 2's grouped scenarios.	74
6.3	Results of Study 2's questionnaire.	80
6.4	Descriptive statistics of participant performance (as a percent) in the training system. Standard deviation is in brackets. IFS = Identifying the correct icon/description based on the sound. SFI = Identifying the correct sound based on the icon/description.	82

LIST OF FIGURES

2.1	The three channel Flow theory.	11
2.2	Vicencio-Moreira et al.'s implementation of their "combo" assistance, featuring aim assistance, differential damage, and player location awareness assistance in the form of icons indicating opponent locations and a minimap.	14
2.3	The four stages of Kolb's experiential learning.	22
2.4	A power function demonstrating the power law of practice.	22
2.5	The three channel flow model with the zone of proximal development added.	24
2.6	Killi's experiential gaming model.	25
3.1	The image participants saw that described the elements of the HUD.	28
3.2	The image participants saw that outlined what they were seeing on the 2D maps.	29
3.3	How the participants were to provide estimates of the opponent's location.	30
3.4	How the participants were to list the information they used to determine the opponent's location.	31
3.5	The three maps used throughout the scenarios.	32
3.6	The final frame of the video for Scenario 1 (a) and a third-person view of Scenario 1 (b), showing the opponent's final location.	34
3.7	The approximate paths the POV and opponent players took in Scenario 1.	34
3.8	The final frame of the video for Scenario 2 (a) and a third-person view of Scenario 2 (b), showing the opponent's final location.	35
3.9	The approximate paths the POV and opponent players took in Scenario 2.	35
3.10	The final frame of the video for Scenario 3 (a) and a third-person view of Scenario 3 (b), showing the opponent's final location.	37
3.11	The approximate paths the POV and opponent players took in Scenario 3.	37
3.12	The final frame of the video for Scenario 4 (a) and a third-person view of Scenario 4 (b), showing the opponent's final location.	39
3.13	The approximate paths the POV and opponent players took in Scenario 4.	39
3.14	The final frame of the video for Scenario 5 (a) and a third-person view of Scenario 5 (b), showing the opponent's final location.	40
3.15	The approximate paths the POV and opponent players took in Scenario 5.	40
3.16	The final frame of the video for Scenario 6 (a) and a third-person view of Scenario 6 (b), showing the opponent's final location.	42
3.17	The approximate paths the POV and opponent players took in Scenario 6.	42
3.18	The final frame of the video for Scenario 7 (a) and a third-person view of Scenario 7 (b), showing the opponent's final location.	43
3.19	The approximate paths the POV and opponent players took in Scenario 7.	43
3.20	What the user sees if they attempt to select that they have no sound.	44
3.21	The performance review.	46
3.22	The result of cutting away the top portions of the map, for the map "Furious Heights."	48
4.1	Demographics for Study 1.	50

4.2	Charts of the descriptive statistic results for the scenario groups, compared between self-rated <i>Quake Live</i> expertise. Error bars are standard error.	54
4.3	Heatmap of location responses for the introductory scenarios. The first column is scenario 1, the second is scenario 2. The rows are, from top to bottom, novice, experienced, and expert. The reticle indicates the opponent's location and the green circle indicates the point-of-view (POV) player's location.	55
4.4	Heatmap of location responses for the visually-dependant scenarios. The left column scenario 4, the right is scenario 6. The rows are from top to bottom, novice, experienced, and expert. The reticle indicates the opponent's location and the POV player's location is in green.	56
4.5	Heatmap of location responses for the auditory-dependant scenarios. From left to right, scenario 3, scenario 5, and scenario 7. From top to bottom, novice, experienced, and expert. The reticle indicates the opponent's location and the POV player's location is in green.	57
5.1	The modified in-game HUD interface.	64
5.2	The icons representations on the sound that appeared on the HUD.	64
5.3	Before training on each set of cues, a brief introduction was shown, and the user could optionally listen to the sounds.	65
5.4	The sets of audio cues.	66
5.5	Basic question type.	67
5.6	The two non-basic question types in the training system.	67
5.7	When the user chose an incorrect option, they were able to see or hear the correct option.	68
6.1	Demographics for Study 2.	71
6.2	Demographics for those 106 participants who underwent training.	72
6.3	Demographics for the 25 participants who completed the follow-up.	73
6.4	Heatmap of location responses for the introductory scenarios. The first column is scenario 1, the second is scenario 2. We compare between the different factors of HUD icons and training to compare the three groups represented by the columns. The first row contains responses of participants who received no scaffolding, the second contains responses from participants who had access to HUD icons and the third contains responses from participants who underwent training. The reticle indicates the opponent's location and the green circle indicates the point-of-view (POV) player's location.	75
6.5	Heatmap of location responses for the visually-dependant scenarios. The left column is scenario 4, the right is scenario 6. The first row contains responses of participants who received no scaffolding, the second contains responses from participants who had access to HUD icons and the third contains responses from participants who underwent training. The reticle indicates the opponent's location and the POV player's location is in green.	76

6.6 Heatmap of location responses for the auditory-dependant scenarios. From left to right, scenario 3, scenario 5, and scenario 7. The first row contains responses of participants who received no scaffolding, the second contains responses from participants who had access to HUD icons and the third contains responses from participants who underwent training. The reticle indicates the opponent’s location and the POV player’s location is in green. 78

6.7 Charts of the descriptive statistic results for the auditory-dependant scenarios, compared between type of scaffolding. Error bars are standard error. 78

7.1 The different categories of audio cues and the relationships between requisite knowledge and the degree to which the other player’s location is revealed. 85

LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
FPS	First-Person Shooter
HIT	Human Intelligence Task
HUD	Heads-up Display
KDE	Kernel Density Estimation
LOF	List of Figures
LOT	List of Tables
MTurk	Mechanical Turk

CHAPTER 1

INTRODUCTION

1.1 Problem and Motivation

Many digital games played today are complex, requiring the player to master of a diverse set of skills [49] in order to succeed. Interestingly, this process of mastering skills to overcome in-game challenges is actually a large part of what make games fun to play [29, 40, 58]. Games that provide optimal challenges and opportunities to acquire skills satisfy a player's need for competence [58], which intrinsically motivates players to continue to play. Because designers of singleplayer games have full control over a player's experience, they often design experiences with these qualities in mind. Designers can maximize a player's ability to develop skills in a way that allows them to overcome challenges and feel competent. Designers can do this by revealing skills in an optimal order, controlling the pacing of the difficulty or rewards, and adapting the game to meet the skill of the player through dynamic difficulty adjustments [35, 51, 29].

But there are cases in which game designers are unable to have so much control over a player's experience. In particular, the challenge level of a competitive multiplayer game is determined primarily by the opponent's skill level. When there is a mismatch in competing players' skill levels, the play experience is unsatisfying because it lacks suspense [2], is frustrating [31], and results in one player feeling bored while the other feels anxious [11]. On top of all this, the weaker player's ability to learn experientially will be compromised [37], not allowing them to improve to a point where they may eventually be well-matched to their opponent.

Because game designers want their games to be enjoyable, and this is best achieved when the challenge level is well suited for the player, they apply a variety of approaches to mitigate this potential issue of skill mismatch. Sometimes a player will be given a rating of their ability, which is used when that player searches for potential opponents. The system can then match them to

similarly skilled opponents [51], and the system will do its best to minimize the difference in skill level between the players. Another approach, used for team games, is to provide asymmetric roles [74] – this allows a player to choose a role that best fits their ability. For example, a player can choose a supporting role that allows them to follow their teammates and assist them from a position that exposes them to less danger. These two approaches do work, but they have a major limitation – they rely on the presence of strangers in order to achieve balance. In doing this, they fail to support social settings where there are specific individuals that the player wants to play with, such as when parents play with their children or a group of friends want to play together. Two other approaches attempt to address this scenario: dynamic difficulty adjustment, and dynamic skill assistance. Dynamic difficulty adjustment refers to when the systems in the game change in order to help a player. An example of this is differential damage dealing in a first-person shooter [7, 30, 74]; the player who is struggling will do more damage than the player who is succeeding. On the other hand, a skill assistance system will assist a player with a particular skill they may be struggling with. One example, again in a first-person shooter, is aim assistance [8, 75, 73] – a tool that helps the player with the skill of targeting an opponent.

While these systems attempt to solve this skill discrepancy, they fail to address the underlying reason for the skill discrepancy – that one of the players hasn't developed one or more of the skills they need to succeed. We propose that game designers should instead be taking what they know about scaffolding novices to experts in singleplayer games and apply similar techniques to multiplayer games. Doing so would help to minimize the amount of time a player must spend struggling to improve without proper guidance. The current attempts at doing this in first-person shooters usually involve a separate tutorial which assumes the player is an absolute beginner at the game. They might start out by describing the controls a player must use to move around and change orientation, then make the player walk up to a target range and shoot various weapons. If a tutorial goes further than this, it might only describe the specific rules that the player needs to know to complete objectives – but no more. With this limitation in mind, we sought to address the problem that novices are failing to learn important skills on their own, leading to extended struggles and in unpleasant play experience.

1.2 Solution

Our solution to address the underlying issue of skill discrepancy – that one player hasn’t learned the skills required to succeed – was to develop a system to provide scaffolding for the weaker player so that they could learn how to use an important skill quickly. Our focus was on one important skill, however, the same principles we applied could be used to scaffold any number of alternative skills.

Our focus was on first-person shooters, and in particular, the game *Quake Live*. In this game – and many other similar FPS games – maintaining some awareness of where opponents are is a crucial skill to learn. Opponents wishing to harm the player (to increase their score) will be actively seeking out other players, and will be trying to determine the best opportunities to attack, to maximize their chances of success. If a new player isn’t also doing the same, they will be constantly surprised by attacks, fail to counter-attack effectively, or fall into an opponent’s trap. This repeated failure would certainly be frustrating to a weaker player, who is trying their best already and may not realize what they are doing wrong – just that they keep failing.

Therefore, we focused on this skill of maintaining awareness of opponent locations, and particularly, maintaining awareness of opponent locations when the opponents aren’t immediately visible. Our solution was to scaffold players to learn about locating opponents through paying attention to the auditory awareness cues that indicate or hint at an opponent’s location.

1.3 Steps to the Solution

There were many steps involved in accomplishing our end goal of scaffolding novices to be able to leverage awareness cues to help them locate opponents, even when those opponents weren’t in their immediate field of view. The initial steps involved first verifying that this was indeed something experts learn how to do, and that novices currently aren’t able to do. Once we had established this, we had to determine how experts are able to locate opponents using awareness cues – and determine which awareness cues to focus on, whether they be visual or auditory cues.

To accomplish these initial steps, we created a custom system that presented hand-picked scenarios to participants. Participants watched the scenarios play out from one player’s point of view (the POV player), and the scenarios always involved one other opponent player. We selected scenar-

ios to highlight different awareness cues or awareness cues that we believed had differing amounts of obviousness. For example, one scenario, utilizing auditory awareness cues, involved the nearby opponent picking up a sequence of five instances of the same item, and so the same sound was heard five times. This was considered obvious because there was only one location on the map where the opponent could pick up five items sequentially. After watching the scenarios, participants responded to them by providing an estimation or guess of the opponent's location and listing the awareness cues they used in making their guess. This system is described in detail in Chapter 3, and was used to conduct our first study, the results of which are outlined in Chapter 4.

Based on the results of this first study, we verified that experts were able to locate opponents using awareness cues during scenarios in which novices struggled to do the same. We found that novices primarily struggled in the presence of auditory awareness cues, which allowed us to clarify our end goal – our next steps focused on auditory awareness cues alone.

We designed two systems with the intent of scaffolding novices to leverage auditory awareness cues. Their focus was to teach novices how to recognize the sound they were hearing, and associate them with particular icons that are used throughout the game to indicate items or objects. We used two approaches – one was a modification to the in-game interface, or heads-up display (HUD), which showed real-time visual iconic representations of the auditory awareness cues that are current audible. The other approach was external to the gameplay, and was essentially a quiz that was designed to promote learning by providing immediate feedback so that participants could learn from their mistakes to hopefully do better when asked the same question again. This approach was heavily inspired by Duolingo¹, a gamified language learning system. The details of these two systems are described in Chapter 5.

Since our previous system of presenting select scenarios to participants and asking them to estimate the opponent's location worked well, we utilized it again for Study 2. This time, to evaluate how well our two system worked.

¹<http://duolingo.com>

1.4 Evaluation

Our primary method for evaluating a player’s ability to locate opponents was our custom system that asked participants to respond to select scenarios involving varying awareness cues of varying obviousness. This system is described in detail in Chapter 3 and was used for studies 1 (Chapter 4) and 2 (Chapter 6). The system utilized 7 scenarios: 2 introductory scenarios where the opponent was visible at the end of the scenario, 2 visually-dependent scenarios, in which visible bullets or smoke trails indicated the opponent’s location, and 3 auditory-dependent scenarios, the sounds heard indicated the opponent’s location.

For each scenario, we asked participants to provide a written description of where they thought the opponent was at the end of scenario, as well as pick out that location on a map. We also asked them to rate their confidence on a scale from 1-5 in which 5 indicated the most amount of confidence. Finally they were asked to list the awareness cues they used. They could add any cue they wanted to the list, as long as it was prefixed with either “I heard,” “I saw,” or, “I noticed.”

From this, we grouped responses by expertise level for Study 1 and by scaffolding given for Study 2, and were able to determine the average performance for each group.

We determined accuracy of the responses by creating one heatmap for each group and scenario combination. This allowed us to visually determine how accurate novices were in comparison to experienced and expert players. For Study 2, we were able to also determine accuracy by evaluating the written responses. This was possible because we had the experts responses for Study 1, which we now knew were accurate. For each scenario, we identified several key words the experts had used. Identifying those words in Study 2 gave us another indicator for how the scaffolding systems performed.

Our other performance metrics, again for each group and scenario combination, were the average confidence, the number of guesses made (because making a location guess was optional), the average number of cues listed that started with “I heard,” and the average number of cues listed that started with “I saw.”

We also evaluated our training system for scaffolding separately, as part of Study 2 (Chapter 6). The last round of the training was designed to test participants on all of the auditory awareness cues, so that the final performance per cue could be determined. There were also two different types

of questions that were asked for each cue – identifying the icon/description combination from the sound, and identifying the sound from the icon/description combination. The performance for each cue, represented as a percentage out of 100, was determined for these two question types as well as overall. Additionally, we re-tested this performance two weeks later, and again used all of the cues and the two question types. This let us compare the change in performance from immediately after training to two weeks later.

1.5 Contribution

This thesis makes two major contributions to understanding how game designers can scaffold novices of complex multiplayer games to develop skills that are likely to increase their success. Scaffolding systems are already used to great effect by singleplayer video games for introducing important skills to novices [29, 28, 40, 58]. Game designers of these games are able to thoroughly play-test their design, and can generally guide the player to complete tasks in a deliberate sequence in order to help them learn new skills. This means that they will have a good idea of the player’s current skill level, at least in terms of the skills their game focuses on, and thus can scaffold each of the player’s interactions with the system such that the player is always given some amount of help or guidance where otherwise they might fail to make process. Designers of multiplayer games have much less control over scaffolding a player’s interaction. This is because the game designer can’t control the game’s challenges, as the difficulty is determined by the other players. The first major contribution of this work is the idea that scaffolding systems can indeed be used to facilitate skill development for multiplayer games, as well as evidence to support its efficacy.

Our second major contribution is in our methods for identifying what skills new players need training in. Generally, multiplayer game tutorials assume a player has no prior knowledge and so they start from the very beginning, showing players the controls to move around, or how to look around and shoot at things. From there they build on to slightly more complex skills, such as how to complete in-game objectives – they generally stick to describing the unique game rules rather than instructing players on any sort of strategy. Tutorials designed in this way could be considered to be using a bottom-up approach, as they start with the most basic skills first. Our approach is the reverse. We started with an examination of what experts were doing that allowed them succeed

in the game, and tried to introduced one of these ideas to novices. Compared to say, learning the keys required to move one’s avatar, the skill we ended up focusing on, locating opponents through the use of auditory awareness cues, is a difficult and complex skill to learn. We believe that by applying our top-down approach to scaffolding multiple complex skills, the performance discrepancies that exist between novice and expert players can potentially be minimized. This would allow for more meaningful social play opportunities that do not suffer from the problems arising from skill discrepancies.

There are also many secondary contributions of this thesis. These include the verification that awareness cues – and particularly the auditory cues – are inaccessible to novices who do not know how to leverage them in the ways experts do, the understanding of the techniques experts use when leveraging awareness cues. Additionally, the systems that were developed are also secondary contributions. The system for evaluating player location awareness, as outlined in Chapter 3, was verified to be a good way of testing the skill of leveraging awareness cues – experts performed better than novices. The two scaffolding systems were verified in Study 2 to be effective for introducing the skill of locating opponents using auditory awareness cues. Both scaffolding systems could be modified to work for a variety of FPS games.

1.6 Thesis Outline

Chapter Two provides a literature review of related work in HCI and games research. This includes player experience in games, the way skill discrepancies are currently addressed in first-person shooters, the skills required to play first-person shooters, and an overview of skill development and learning as it applies to games.

Chapter Three describes the system that was developed to evaluate how well players of various skill levels are able to locate their opponents, which we refer to as “opponent location awareness.” The system uses scenarios to test players, so the process players go through when responding to scenarios is described, as well as each of the seven scenarios themselves. The questionnaires that were used are also described, as well as the performance review that was designed with the intention of providing some incentive to participate.

Chapter Four presents the first of three studies – the purpose of this first study being to deter-

mine the strategies experts utilize when determining the locations of opponents and to confirm the circumstances under which novices are unable to locate opponents. A description of the procedure is given, followed by an explanation of how participants were recruited and their demographics. Finally the scenario and questionnaire results are presented and analyzed.

Chapter Five details the design of two scaffolding systems that were inspired by the results of Study 1. The first approach involved modifying the in-game heads-up display in order to provide an iconic visualization of the sounds players were hearing during the scenarios. The second approach involved a training system that was developed outside the game.

Chapter Six presents the second study, which involved testing the two scaffolding systems in an experiment with a design similar to Study 1 as well as evaluating the efficacy of the training system. Like Study 1, a description of the procedure is given, followed by an explanation of how participants were recruited and their demographics. The scenario and questionnaire results are also presented. For the evaluation of the training system, the procedure, recruitment methods, data analyses, and results are presented for both initial training as part of a larger experiment and a re-test that followed two weeks after the initial training.

Chapter Seven discusses many of our thoughts regarding the limitations of the studies we did and of the systems we created. It also includes a discussion of directions for future work.

Chapter Eight concludes this thesis, providing a summary of our findings and our contributions.

CHAPTER 2

RELATED WORK

2.1 Games and Play Experience

Video games are more popular than ever. More money is spent on video games than movies and music combined [17] and four in five households own a device that they use to play games on [70]. The majority of gamers play multiplayer games, and they do so on a weekly basis [70]. For example, 67 million players are playing the competitive online team game League of Legends [56].

First-person shooter (FPS) games are particularly popular. Many consider the genre as having started with *Wolfenstein 3D*¹, with the first networked multiplayer 3D FPS, *Doom*², being released shortly after. *Doom* was so influential that FPS games were initially called “Doom clones” [69]. More recently, the *Call of Duty*³ series has sold approximately 146 million copies over the entirety of the franchise [63]. Currently, the most popular PC FPS is considered to be *Counter-Strike: Global Offensive*⁴ [54], which has sold over 21 million copies [65] and is currently played by over 300,000 concurrent players on average [64].

With these large numbers of people playing games, researchers have asked what it is about games that makes them so enjoyable for the player. In describing how and why players are motivated by games, two important theories are self-Determination Theory (SDT) and Flow theory.

Self-Determination Theory [57, 58] focuses primarily on the ideas of intrinsic and extrinsic motivations, and the differences between them. Ryan and Deci [57] define intrinsic motivation as “doing something because it is inherently interesting or enjoyable,” and extrinsic motivation as “doing something because it leads to a separable outcome.” Understanding intrinsic motivation

¹id Software, 1992

²id Software, 1993

³Infinity Ward, Treyarch, Activision, etc. 2003-2015

⁴Valve Corporation, Hidden Path Entertainment, 2012

is of particular importance as games are known to create enjoyment through intrinsic motivation [23]. Ryan and Deci propose that games are motivating because players experience feelings of autonomy, competence, and relatedness [58].

- Feelings of *relatedness* are experienced when a person feels connected to others. Multiplayer games facilitate by allowing players to interact with each other.
- Feelings of *competence* come from completing challenges and being effective [58]. Games support this by offering opportunities to acquire new skills, providing challenges that players can overcome, and giving players positive feedback [58].
- Feelings of *autonomy* involve a player's willingness to complete a task, or their volitional engagement. Games support this because they are played for interest or for personal value [58].

A sub-theory of SDT, which focuses on the factors involved in supporting intrinsic motivation, is Cognitive Evaluation Theory (CET). In CET, feelings of competence and autonomy are what produce variability in intrinsic motivation. An important detail of CET is that feelings of competence must be accompanied by a sense of autonomy in order to enhance intrinsic motivation [57].

Another important model that has been applied to games [11] is Csikszentmihalyi's [14, 15] theory of "flow". Flow theory describes the state in which one is so fully immersed in an experience that nothing else matters. Activities that induce flow are well matched to a person's abilities – they are not boring, and do not produce anxiety. He identified four major components of flow that individuals experience, and two components of flow that relate to how the task itself supports the flow state [15]:

- The individual will experience...
 - "*the merging of action and awareness.*" The person will be aware of their actions, but not be aware of their increased awareness.
 - "*the centring of attention on a limited stimulus field.*" The person will ignore distracting stimuli and only concentrate on their actions. They will focus only on the present or immediate future. Distracting thoughts will be temporarily forgotten.

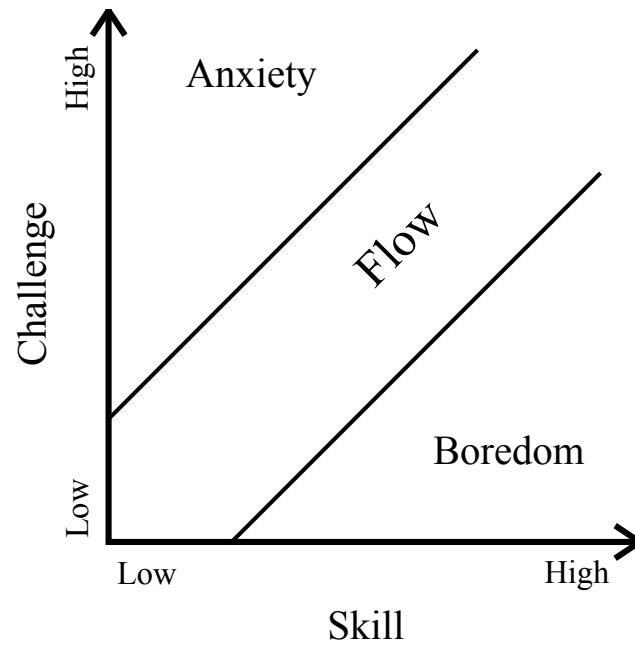


Figure 2.1: The three channel Flow theory.

- a “*loss of self-consciousness.*” Because the individual is so focused on the task, any thoughts involving one’s ego become irrelevant.
- being “*in control of [one’s] actions and of the environment.*” The individual isn’t aware of this control, but they’re also not worried about any lack of control.
- The task requires...
 - “*noncontradictory demands for action,*” and “*clear, unambiguous feedback.*”
 - “*no goals or rewards external to itself.*” It should be intrinsically enjoyable.

The three-channel flow model is based on the idea that people are aware of challenges requiring them to act, and they are aware of their own skills to cope with those challenges [15]. Flow occurs when the current challenge matches their skills. If instead, their skills are greater than required for the challenge, boredom will result, and if their skills are insufficient for the challenge, anxiety will result. This relationship is shown in Figure 2.1.

2.2 Game Balancing

It is well known that a player's experience suffers when the game's challenges are poorly matched to their ability [2, 11, 31]. In multiplayer games, this challenge is determined by the other players, not by the game's systems [51]. Therefore, there are a variety of approaches game designers use to try to address this problem, with two common approaches being matchmaking and skill assistance.

2.2.1 Matchmaking

In popular games with a large pool of players – for example, *Dota 2*⁵, *League of Legends*⁶, *StarCraft 2*⁷, *Counter-Strike: Global Offensive*⁸, *Halo 3*⁹, or *Quake Live*¹⁰ – it is possible to utilize a matchmaking system to match players of similar skill [51, 46]. By matching players of similar skill, the challenge of the game becomes matched to the player's abilities. These systems have limitations, such as having to compromise if there aren't currently enough players at your skill level who also want to play, or when a player's performance is inconsistent [74]. More importantly, they do not work during social play settings, where certain groups or individuals want to play together, such as when friends play socially or parents play with their children.

2.2.2 Skill Assistance and Difficulty Adjustment

Skill assistance and difficulty adjustment are two similar approaches used to improve a weaker player's relative in-game performance. Skill assistance involves directly helping a player with a skill they haven't yet mastered [8, 75, 74], while difficulty adjustment helps the player less directly, by manipulating the game to change the difficulty of the challenge [7, 10]. Both skill assistance and difficulty adjustment can be applied dynamically or statically [4, 7, 10, 16, 74], and both can be either hidden from or disclosed to the player [7, 10, 16].

In competitive games, skill assistance can help players by directly providing assistance with a

⁵Valve Corporation, 2013

⁶Riot Games, 2009

⁷Blizzard Entertainment, 2010

⁸Valve Corporation and Hidden Path Entertainment, 2012

⁹Bungie, 2007

¹⁰id Software, 2010

particular skill, and difficulty adjustment can help by making the challenge easier, which improves the player’s performance. For example, consider two different commercial racing games, *Forza 4*¹¹ and *Mario Kart 8*¹². In *Forza 4*, a player can enable driving assists such as automatic braking, which directly assist the player with one aspect of the skill of high-performance driving. On the other hand, *Mario Kart 8* changes the challenge of the game by giving weaker players more beneficial items, such as speed boosts or shells that can temporarily disable a player in front of them.

Both skill assistance and difficulty adjustment have been researched to determine their efficacy as well as their impact on a player’s experience. Vicencio-Moreira et al. [75, 73, 74] used aim-assistance extensively – a skill assistance – and combined it with a difficulty adjustment – differential damage dealing – to eventually balance a competitive first-person shooter for players of differing skill levels. Another approach for FPS games by Baldwin et al. [7] used differential damage dealing alone, and Bateman et al. [8] also used aim assistance – although for a 2D shooter game. In balancing a racing game, Cechanowicz et al. [10] used a combination of speed boosts, acceleration boosts, and steering assistance to dynamically balance their game – two difficulty adjustments and one skill assist.

Skill assistance and difficulty adjustment systems can also be applied dynamically or statically. As a simple example, consider the typical scenario of choosing between “easy,” “medium,” or “hard” difficulty when you first begin playing a new singleplayer game – this is an example of static difficulty adjustment [4]. On the other hand, dynamic difficulty adjustments evaluate the state of the game before making adjustments that aim to balance the game [35]. The same is true for dynamic skill assistance. An assist that globally helps players aiming with the analog joystick on a gamepad [25, 75] is a static skill assist while Vicencio-Moreira et al.’s [74] final implementation of aim assist was dynamic, as the assistance level changed depending on the score differential.

Considering our two commercial racing game examples from earlier, *Forza 4*’s braking assistance is a static skill assist because it is simply turned on or off depending on each player’s preference, while *Mario Kart 8*’s difficulty adjustment is dynamic – it adapts to the situation and provides more assistance, in the form of more powerful items, when the distance between players is higher.

¹¹Turn 10 Studios, 2011

¹²Nintendo EAD Group No. 1, 2014



Figure 2.2: Vicencio-Moreira et al.’s implementation of their “combo” assistance, featuring aim assistance, differential damage, and player location awareness assistance in the form of icons indicating opponent locations and a minimap.

Assistance systems and difficulty systems can also be disclosed to the player, meaning it’s obvious to the player that they are being assisted, or obscured, so that it’s less obvious to the player that they are being assisted. Any time the player is given a choice to change the difficulty level or toggle a skill assist, the system can be considered disclosed – this means that all types of static systems can be considered as disclosed to the player. In the case of dynamic difficulty adjustments, whether or not these are obscured from the player is debatable. For example, Depping et al. [16] argue that the dynamic difficulty present in *Mario Kart*, the differential powerups, is obvious enough to be considered disclosed.

Even though many have claimed that disclosing assistance or difficulty adjustment would harm a player’s experience [4, 10], Depping et al. [16] found, somewhat surprisingly, that disclosure of a skill assistance did not detract from play experience. They specifically looked at whether the disclosure of skill assistance would impact player enjoyment. They utilized a dynamic skill assistance, which was at times disclosed or hidden from both players. When disclosed, the current assistance level was explicitly displayed to players alongside their score.

Of the recent work in game balancing with skill assistance and difficulty adjustments, the most interesting and relevant work relating to FPS games has been the work by Vicencio-Moreira et al.

[75, 73, 74]. In their three papers, they started out with aim assistance alone, trying to balance both a singleplayer and multiplayer first-person shooter, but found that even with a dynamic system that adapted to the changing player scores, aim assist alone was insufficient for balancing a competitive multiplayer FPS game with novice-expert pairings [73]. In the end, a combination of aim assist, differential damage dealing, and opponent location awareness assists (using a minimap as well as an icon following the opponent, see Figure 2.2) were required to balance the game [74].

While skill assistance systems and difficulty adjustments have been shown to work relatively well, they do have some limitations. For example, in a first person shooter, skill assistance may be applied to help a player aim, yet the player may be lost in the 3D environment and thus no amount of aim assist will help them perform better. Furthermore, there are situations in which skill assistance and difficulty adjustment could also negatively impact a player's skill acquisition. For example, aim assistance may teach a player that they only need to point near an opponent to succeed – the player learns how to use the assistance rather than learning how to aim properly. Finally, there are settings in which both skill assistance and difficulty adjustment are inappropriate, such as more formal competitive settings where such systems would be considered cheating [42, 81].

2.3 Skills in First-Person Shooter Games

To provide skill assistance for players, we first need to understand what skills players utilize in games. While we look at the skills used by players from the perspective of first-person shooters, many of these skills are also present in other games.

In developing an instrument that could be used by those familiar with the skills required to play a particular game, Norman [49] identified six possible factors of abilities that players require in order to play a game. These factors included:

- *Perceptual-Motor Abilities*: Includes perceptual speed, pattern recognition, object identification, simple and choice reaction time, tracking, targeting, timing, rhythm, and response mapping.
- *Cognitive Processing Abilities*: Includes the processing or interpreting of information communicated through text and speech as well as hidden object detection.

- *Problem Solving Abilities*: The ability to directly solve puzzles or problematic situations arising from the games rules or mechanics.
- *Information Utilization Abilities*: Involves managing in-game resources such as health or ammo, using information from memory, and filtering out irrelevant information.
- *Persistence*: Having enough patience to put up with any tedious or boring aspects of the game.
- *Human-Human Interaction*: The ability to handle communicating with the other players in the game.

Based on Norman’s descriptions of these factors, four of these six factors are most relevant to FPS games. These are perceptual-motor abilities, cognitive processing, problem solving abilities, and information utilization. We list each relevant factor as we examine each upcoming FPS skill.

When identifying the skills used in first-person shooters, it is important to be clear about the definition of the genre and the actions players make during play. Voorhees et al. [76] point out that many authors and researchers fail to adequately describe the genre they are working with, and resort to describing the genre only briefly, as if everyone already knows exactly what an FPS is. Adams [5] describes shooters in general (2D and 3D) as games involving “action at a distance,” and calls out aiming as a key skill. Adams also mentions the importance that the 3D world has in a first-person shooter – as a player navigates the environment, the game’s physics resemble those of the real world. Adam’s definition is succinct, but it lacks detail, and others go further with their definition of what makes up a FPS game by first establishing what makes up a genre and then naming the actions that players take when playing a game of a particular genre.

King and Krzywinska [38] describe the first-person shooter genre in terms of its “key” and “supporting” hooks, which differentiate one game genre from another. These two hooks are equivalent to what many would call the “core mechanic,” defined by Salen and Zimmerman [60] as “the essential play activity players perform again and again,” although they point out that the core mechanic can also be a combined collection of actions. Conveniently, both King and Krzywinska as well as Salen and Zimmerman describe their theories using first-person shooters as examples. Salen and

Zimmerman use the FPS game *Quake*¹³, and describe its core mechanic as “the set of interrelated actions of moving, aiming, firing, and managing resources such as health, ammo, and armor.” King and Krzywinska describe first-person shooters as the “key hooks” of navigation, shooting, and taking cover, in addition to the “resource hooks” of monitoring ammunition, health, and supplying the player with weapons and equipment.

An alternate approach to determining the skills players use in FPS games is to consider the ways in which players cheat – or in other terms, the skill assists they use in order to gain an unfair advantage over their opponents. The most common techniques involve the use of an “aimbot” or “wall hack” [42, 81]. Aimbots help players target their opponents by moving the targeting reticle towards the opponent’s location [79]. The most obvious aimbots will simply lock a player’s crosshair onto the nearest opponent’s location. A wall hack allows players to see through walls for the purpose of determining the location of opponents, allowing a player to aim towards opponents before they come into view [79]. A wall hack can be also be combined with another type of cheat, extrasensory perception or ESP [79], which shows the cheater additional information about the opponents, such as their current health and equipment. This combination allows players to easily know whether it is safe to attack an opponent, or if the opponent should be avoided.

Based on these definitions, the way players are cheating, and that the unique actions players perform could each be considered separate skills, it’s clear that the most fundamental skills of the genre are those of movement (specifically the navigation of a 3D environment [24, 38]) and shooting. These are both perceptual-motor abilities, and every first person shooter involves these skills. The remaining skills or “resource hooks” [38] of managing health, ammo, armour, and weapons are primarily information utilization skills. Determining opponent locations involves the skills of both cognitive processing and information utilization. Cognitive processing specifically when scanning a scene looking for opponents, and both cognitive processing and information utilization when trying to identify the opponent’s location by listening to sounds.

¹³id Software, 1996

2.3.1 The Use of Sound

The skills of information utilization and cognitive processing rely heavily on the use of sound. Sounds in games can be immersive or informative; however, our focus is on informative sound. In first person shooters, sounds that are heard in response to player actions can convey a lot of useful information, and are a key part of how an opponent's location can be determined without the use of sight.

Gaver [26] proposed an approach to utilize sound to convey information to a user regarding actions in user interfaces and coined the term “auditory icon.” These auditory icons are based on real-world intuitions that people already have, Gaver gives an example of a file hitting a mailbox to signal that an email with an attachment is received, with a larger file making a more “weighty” sound. This approach has similarities to the approach game designers take when including sound effects in games, and so the term “auditory icon” could also apply to games to describe the informative sounds that convey useful information.

In real-time collaborative software or groupware, maintaining awareness of other team member's actions is an important component of ensuring that the interaction is efficient and fluid [33]. To assist users with maintaining awareness, sound has been explored as a method of conveying information about the actions of others. For example, Gaver [27] re-utilized his auditory icons in groupware settings in order to convey information about the actions of others. He states that although we may often both see and hear something, it is also possible, and often quite valuable, to hear something but not see it – and additionally, hearing an event does not necessarily take away one's focus on another event [27]. Gaver tested these ideas with ARKola [27], a system that assisted distributed pairs with continuous auditory feedback to operate a simulated bottling plant. As the representation of the plant was too large to fit all at once on the screen, participants had to rely on the auditory cues to maintain awareness of the plant's current state. For example, participants could hear supplies moving along the conveyor, bottles being capped, and supplies being crashed or spilled.

For the purpose of identifying design patterns, Ng and Nesbitt [47] examined the application of informative sound design in a FPS game, *Battlefield 3*¹⁴. First, they emphasize that although their

¹⁴EA DICE, 2011

focus is on informative sound, often sounds can be both immersive and informative. The mapping of a sounds to a real-world equivalent allows a player to more quickly recognize the meaning of a sound, allowing for a more intuitive response [47]. Next, they identified three types of sound effects: pre-emptive sounds, reactionary sounds, and feedback sounds. They also give an example for each: a pre-emptive sound is when, for example, a grenade is heard landing on the floor nearby the player – the player has an opportunity to respond to the sound, such as by moving to a safer position; a reactionary sound is, for example, when a player fires towards an opponent but misses – the opponent now knows where the player is and can react accordingly; a feedback sound is, for example, when a player gets hurt and the player’s avatar can be heard grunting or making some other sound to indicate pain – information regarding the player’s health is gained.

In exploring the use of audio within games, Jørgensen [36] had players play a game with sound and then again without sound. She demonstrates how taking away sound impacts a player’s orientation and awareness, as well as making some information less accessible. While some of her study participants admitted that they did not think missing sound would impact they game they were playing (*Warcraft III*¹⁵, a real-time strategy game), they described the experience without sound as feeling as if they “lost control.” Jørgensen describes how sound is used “as an information system that enables listeners to pick up a higher amount of data compared to the visual system,” for example, by alerting players of their unit’s death in an RTS game without the unit needing to be on the screen.

A common term that comes up is “acousmatic,” [36, 66] which refers to a sound which can be heard but the source of it cannot be seen. In the 3D environment of a FPS game, the player often has the choice to allow a sound to continue to be acousmatic, or to seek it out in order to visualize it. Stockburger [66] gives an example of this situation. He describes a situation in which a player hears a sound effect known to be connected to opponents, and in response to that sound the player re-positions their point of view in the direction of the sound in an attempt to locate the source.

¹⁵Blizzard Entertainment, 2002

2.3.2 The Use of Strategy

The skills of resource management, information utilization, and cognitive processing influence the strategies that players employ as they play first-person shooters. By strategy, we refer to the important decisions that players make within the game, such as deciding to pick up an item or deciding to retreat from an opponent.

In online strategy guides for the *Quake* series and similar FPS games, the importance of controlling the items on the map is often emphasized [21, 50]. A player who collects more health, armour, and weapons than their opponent will have an advantage over them. Players can take this to extremes by ensuring they are present when important items become available for collection again (or “respawns”). This is done by knowing how long it takes an item to respawn and the time when the item was last taken [50]. This is a common strategy used by experts to ensure that they have more available resources than their opponents. If a player knows they have more resources than their opponent, they can attack them knowing that they have an advantage.

Conroy et al. [13] specifically looked at this skill of threat assessment in FPS games, and how players can utilize information to decide whether or not to flee or fight. They presented participants with a variety of scenarios in which both their own and their enemy’s status (including health, held weapon, and distance) were known, and asked them to rate the threat level and how they would react. They found that when participants had all of the available information about a situation they generally agreed about how threatening it is and what response it required. However, in their scenarios, they found that actual in-game responses matched the agreed-upon responses only when the scenarios were following expert players. This suggests that all of the information is available, yet only experts are able to properly make use of it.

2.4 Skill Development and Learning

When providing a scaffolding system to assist in skill development or learning, it’s important to understand the concepts behind the influential models in skill development and learning. Therefore, we present two models – first, Fitts and Posner’s three stages of skill development, and second, Kolb’s experiential learning model. Following this, we examine the role these two models have

when a player is learning how to play a game. Finally, we provide an overview of the ways in which players are currently expected to learn how to play multiplayer first-person shooters by surveying the systems used by commercial games.

Fitts and Posner’s [20] three stages of skill development has been an influential model and has been applied to both user interface design [12, 32] and games [55]. The three stages consist of the cognitive stage, associative stage, and autonomous stage.

During the cognitive stage, the user focuses on *what* needs to be done, and starts to form conceptions about the task [20]. The user develops and understanding of the task, and can gain this either through direct instruction, or through visual observation or images of the task [12]. Schneider and Shiffrin [62] characterize it as being a slow and attention demanding process, and say that its execution can be interrupted by other tasks and that it is volitional – the task can be avoided or stopped. The user’s performance at this stage can be inconsistent as they try different approaches [12].

During the associative stage, the user focuses on *how* the task is done [20], and begins to improve their performance when executing the task. These performance improvements arise due to subtle adjustments users make in their execution as they practice the task [12]. Users may spend years in the associative phase before before transitioning to the autonomous stage [12], and in some cases, if the task is complex, the practice that users must commit to before reaching the next stage is deliberate and just beyond their competence level [3, 18].

At the autonomous stage, the user is able to complete the task with a high amount of automaticity – with little to no conscious thought or attention [20]. Schneider and Shiffrin [62] characterize the tasks at this stage as being fast, not attention-demanding, being parallel – with some operations occurring together, and non-volitional – often the process becomes difficult to interrupt once started. Cockburn et al. [12] gives an example of a touch typist who continues typing a few pending keystrokes when interrupted.

Another important model for learning new skills is Kolb’s [39] theory of experiential learning. Kolb defines experiential learning as “the process whereby knowledge is created through the transformation of experience,” and a central idea in the theory is the interplay between expectation and experience. Kolb argues that learning primarily occurs when the outcome of an experience does not match one’s expectations – the violation of expectation causes one to adapt and learn. Another

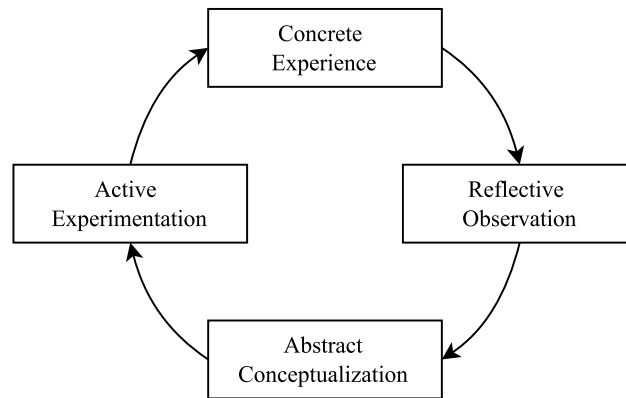


Figure 2.3: The four stages of Kolb's experiential learning.

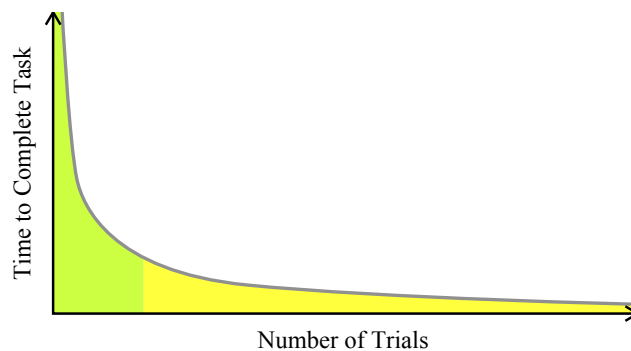


Figure 2.4: A power function demonstrating the power law of practice.¹⁶

central idea of the model is that learning is a continuous process. Kolb argues that ideas are constantly being formed and re-formed from experience, and that all learning is really re-learning – one's initial ideas may just be naive or inaccurate. The model is represented as four separate but continuous stages of concrete experience, reflective observation, abstract conceptualization, and active experimentation (see Figure 2.3). The learner first has a new experience, then reflects upon the experience, with some focus on observing how their initial expectations matched or didn't match their actual experience. Next, the learner forms new ideas or modifies their existing ideas and then applies those ideas in the world to evaluate them, which once again leads to a new concrete experience.

Practice is an important concept in understanding skill acquisition, and in particular, the idea of the power law of practice [45] is useful for describing the rate in which users learn a new skill, on average. As a user learns a new skill, their performance tends to follow the curve of a power

¹⁶Adapted from a public domain image by Hay Kranen.

function. This means that the early parts or first stage of the learning process is when the majority of performance increases are present and after some practice the gains gradually diminish and performance begins to level off.

2.4.1 In Games

Games are considered by many to be powerful learning tools. They are able to transform novices into experts, training them to perform long, complex, and difficult tasks, and they can do this while also providing an engaging, motivating, and enjoyable experience [28, 29, 40]. Many have attempted to understand or explain how this is being accomplished – we focus on outlining the work by Gee [28, 29] and Killi [37], as well as the concept of direct instruction.

Killi [37] proposed a model for game-based learning environments based on Kolb's experiential learning theory [39], flow theory [15], and game design. The model proposes that gameplay can be linked with experiential learning to facilitate flow. Killi incorporates flow theory into his model for a number of reasons. First, the alternatives to flow are boredom and anxiety, neither of which are desirable experiences. Second, the flow state has been shown to have a positive impact on learning [78]. Killi considers the zone of proximal development as adding to the flow channel, extending it slightly (see Figure 2.5). The zone of proximal development refers to what a learner can achieve with some guidance or scaffolding, which allow the learner to tackle a slightly more challenging task than they could have completed on their own [77].

Good game design contributes to keeping players in the flow channel. Games can be considered as being composed of many small, linked problems that players must overcome in order to make progress [37]. Many games are able to keep players both motivated and engaged throughout the experience [40] and a large part of this is by maximizing the time players spend in the flow state, where the challenges are well-matched to their abilities. Good games will keep players in the flow state as the player improves by constantly increasing the difficulty of the game [40, 37], and this leads to players constantly learning and improving.

Killi's model incorporates these concepts of flow, and in particular how flow is supported by good game design to propose his experiential gaming model, where problems and solutions are

¹⁷Reprinted from *The Internet and Higher Education*, Volume 8 Issue 1, Digital game-based learning: Towards an experiential gaming model by Kristian Killi, Pages 13-24, Copyright (2005), with permission from Elsevier

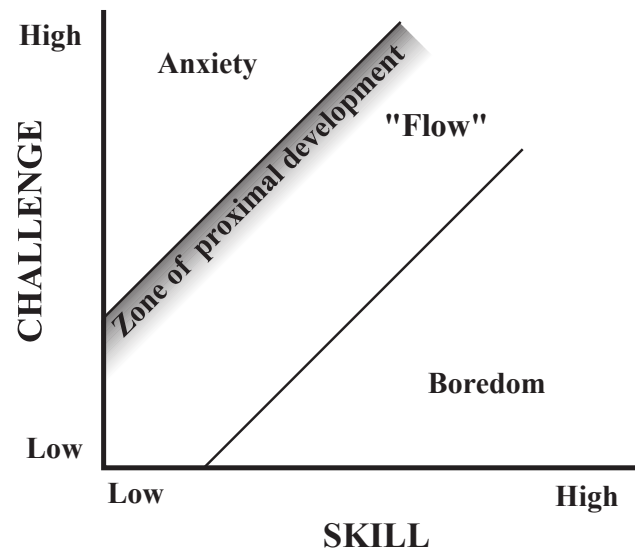


Figure 2.5: The three channel flow model with the zone of proximal development added.¹⁷

considered to be ideal when at a challenge level that is matched to the player's ability. By keeping the challenge level within the flow channel (or the flow channel including the zone of proximal development if scaffolding is utilized), the player is able to overcome challenges by solutions that they themselves generate (or they generate with guidance of the scaffolding system). Killi proposes that as the player's skill level increases, the challenge's difficulty should also increase – as is also proposed for flow theory.

Killi's [37] model (Figure 2.6) contains two main phases, the *ideation* phase and the *experience* phase. The ideation phase is where a player generates ideas and potential solutions to problems or challenges. The solutions generated in the ideation phase can be broken down into *preinvasive ideas*, meaning that the constructs of the system are not considered, and *ideas*, for which the player has enough experience to consider the constraints of the system. After idea generation, the potential solutions are tested in the experience phase, which resembles Kolb's [39] experiential learning model in that it is a continuous loop. In this phase, the player tests and observes the outcomes of their previously generated solutions. After testing, the player can consider the additional constraints and return to the ideation phase to generate a new potential solution.

Gee [28, 29] has explored how good games promote learning by listing the principles of learning they use. He lists thirteen principles of learning, grouped into three sections: empowered

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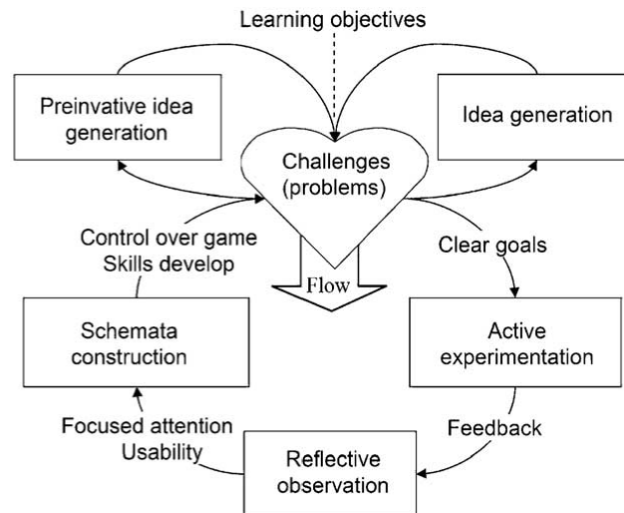


Figure 2.6: Killi's experiential gaming model.¹⁸

learners, problem solving, and understanding. We list and describe the principles of learning from the problem solving section, as they are the most relevant.

- *Well-ordered Problems:* Early problems help guide players into generating better potential solutions for later problems.
- *Pleasantly Frustrating:* Learning works when the problems players are facing are just beyond their skill level. This might be thought of as the problems being within the zone of proximal development.
- *Cycles of Expertise:* Gee describes expertise as being formed through “repeated cycles of learners practicing skills until they are nearly automatic, then having those skills fail in ways that cause learners to have to think again and learn anew” [28, 61]. This is what boss battles do.
- *Information “On Demand” and “Just in Time”:* Games provide players with the textual information only when it’s required – no manual should be required to play.
- *Fish Tanks:* Games can create simplified systems that highlight a few key variables and their interactions. This is often done in the first part of the game, or as a tutorial.
- *Sand Boxes:* Learners in games can be put into situations that feel real but actually have reduced danger. This reduces the stress on the player.

- *Skills as Strategies*: It is better to practice a skill with context, such as part of solving a problem or accomplishing a goal.

As an alternative to these experiential learning processes, direct instruction can be provided. This is often done in the form of a dedicated tutorial [51, 71]. Andersen et al. [6] tested the impact of tutorials on games of differing complexity. They found that providing tutorials for complex games increased play time significantly. Simple games, however, were not impacted by the presence of a tutorial; the mechanics could be discovered easily through experimentation and so a separate tutorial was not helpful.

2.4.2 First-Person Shooters Examples

Some FPS games – particularly single-player games – include tutorials that can be played separately. Two representative examples include *Half-Life*'s¹⁹ classic hazard course and *Counter-Strike: Global Offensive*'s weapon course. *Half-Life* is primarily a singleplayer game, while *Counter-Strike: Global Offensive* is a multiplayer game. Both of these examples are designed to teach the player the basics of the games systems, including moving, shooting, and interacting with objects in the environment. Neither of these tutorials go further than this, and instead expect the player to play the game to experientially gain the rest of the requisite skills. If a novice attempted to play a competitive multiplayer game after undergoing only this minimal training, they may be overwhelmed [11] when they realize they are unprepared for the challenge.

The choices for training beyond what current tutorials provide are currently limited to online guides and tools designed to improve ones reaction time and aim²⁰. Another – now unavailable – option was “FPS Trainer” [67, 68], which attempted to teach players about timing, positioning, and appropriate weapon selection [67] through real-time in-game feedback systems. Unfortunately, the efficacy of this tool is unknown.

¹⁹Valve Corporation, 1998

²⁰For example, <http://aim400kg.com> and <http://www.aimbooster.com>

CHAPTER 3

A SYSTEM FOR EVALUATING PLAYER LOCATION AWARENESS

Experts of first-person shooter games seem to have managed to develop the skill of locating opponents in the 3D environment – both those who are within sight, and those outside of their immediate field of view. They have acquired this skill either experientially or with the guidance of an online guide [59, 21]. However, exactly how they accomplish this, as well as the circumstances under which they are able to accomplish this has never formally been investigated. Determining how experts locate opponents was the first step towards providing scaffolding for novices to assist them in acquiring this skill.

3.1 Design of the System

In designing a system to evaluate how players locate opponents, there were a few requirements we felt were extremely important. First, we were concerned about repeatability – each player should be responding to the exact same situation as the player before him or her. Second, we were concerned about scalability – each situation should be able to be responded to quickly, so that many situations can be presented. Finally, we were concerned about access to experts.

To meet the requirement of repeatability, we decided that participant responses should be given in return to set, predefined, scenarios. This took the form of a pre-recorded video of game-play footage rather than live play. To meet the requirements of scalability and access to experts, we decided that the system should be built to be deployed online, where experts players could be found more easily, the responses could be given fairly quickly, and different participants could answer questions in parallel, allowing us to gather data quickly.

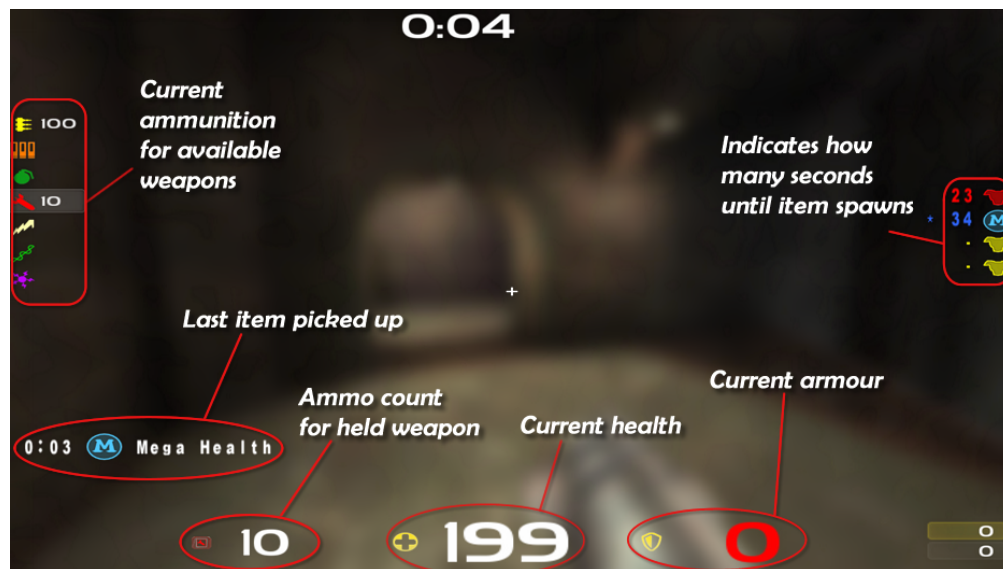


Figure 3.1: The image participants saw that described the elements of the HUD.

The system revolves around the concept of viewing a scenario video involving an example interaction between two players – one through whom you view the situation, and another who may or may not be directly visible, and answering questions in response to the scenario.

After completing a demographics questionnaire, participants were given a brief explanation of the in-game HUD (Figure 3.1) and how to read the top-down 2D map (Figure 3.2). After this, participants watched a number of video scenarios. After watching each video, participants were asked to provide an estimate of the opponent's location (see Figure 3.3). This was done in two ways, a written response, and a response based on a top-down two-dimensional visualization of the map featured in the scenario. Participants could write whatever they felt like for the written response, but for the map response they were required to click a single point on the map. Additionally, they were asked to provide an estimation of their confidence in their response. This was recorded on a scale of 1 (meaning "I don't know where the other player is") and 5 ("I know where the other player is"). Participants also had the option of choosing to select "I don't know" for both types of location estimations. Selecting this option prevented them from providing estimations and assigned them a confidence rating of 1.

Following the location estimate responses, participants were asked to provide a list of information they used to determine the location they selected (see Figure 3.4). By default, the list contained the following options: "I saw the player," "I heard footsteps," "I heard jumping," and "I heard an

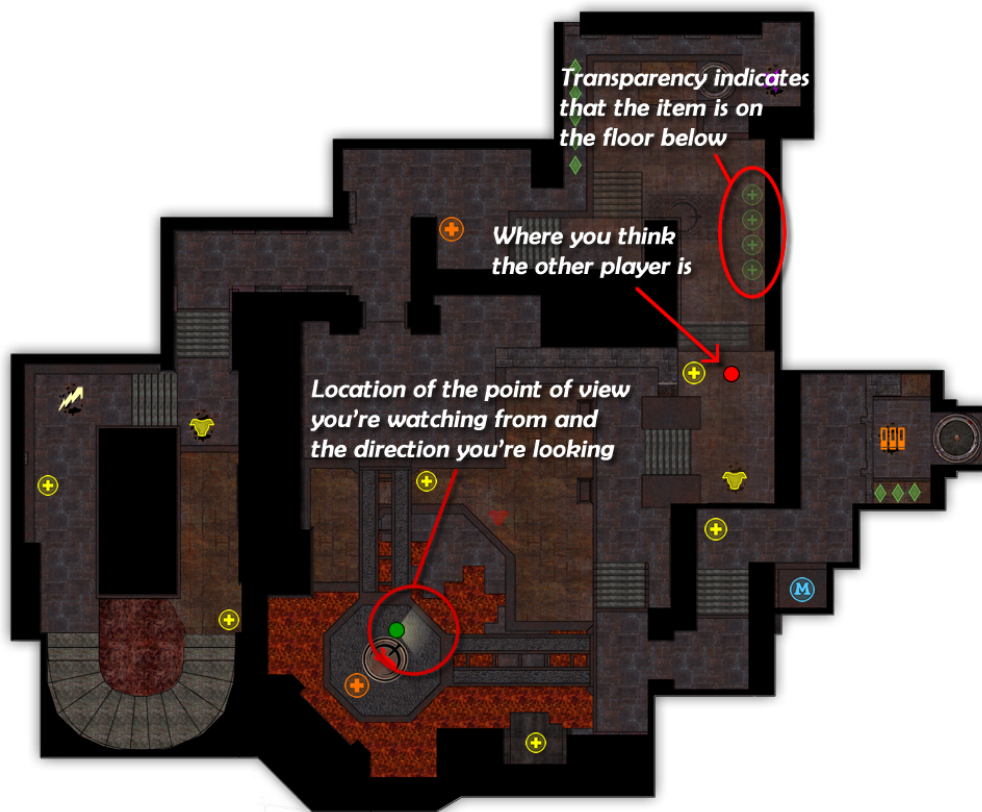


Figure 3.2: The image participants saw that outlined what they were seeing on the 2D maps.

1. Please describe where you think the other player might be (when the video pauses at the end).

☐ I don't know.

How confident are you?

Please Choose: ▼

2. Where do you think the other player might be on the map?
(Click on the image)

☐ I don't know.



How confident are you?

Please Choose: ▼

Figure 3.3: How the participants were to provide estimates of the opponent's location.

3. What information led you to these conclusions? Please list all items separately.
(If you don't have any idea where the other player is, then leave this blank.)

- ☐ I saw the player
- ☐ I heard footsteps
- ☐ I heard jumping
- ☐ I heard an item pickup

Add an item to the list:

I heard
I saw
I heard
I noticed

Enter a new item

Add

Continue

Figure 3.4: How the participants were to list the information they used to determine the opponent's location.

item pickup.” Participants could easily add new options to the list. To do this, they selected a prefix of either ”I heard,” ”I saw,” or ”I noticed,” filled out an associated text box, and clicked the ”Add” button. Options that were added to the list during one scenario would be visible to the participant on later scenarios, so they could quickly check off the same item rather than adding it to the list again.

After completing all the scenarios, participants were then asked to complete a questionnaire asking them to rate the importance of various in-game tasks, and the difficulty of the tasks they completed earlier on. Finally, they were given a text area in which they could share their thoughts regarding the relative importance of the cues.

After the experiment, after completing all of the scenarios and the final questionnaire, participants had the opportunity to review their performance. The solutions to the scenarios were shown in comparison to the locations the participant chose. In addition to this, a list of the information a player could have used to determine the correct location was also presented. This review process was used to encourage participation, and promoted the experiment as a way in which participants could learn to test and improve their opponent locating skills.

3.2 Scenarios

Scenarios were chosen based on my own expertise, and attempted to focus on requiring differing information to locate the opponent, so that we could see what strategies expert players used under various circumstances. After introducing the maps featured in the scenarios, each scenario is described separately.

3.2.1 Game Maps Used

A total of 3 maps from *Quake Live* were used within the scenarios. They were chosen due to their relative popularity for duel mode, while still being played by players of other game types such as free for all (also known as deathmatch) or team deathmatch. Since *Quake Live* is an updated re-release of *Quake III Arena*, two of the maps were also featured in the original release of *Quake III Arena* [22], meaning that they have been playable since 1999. The two maps from *Quake III Arena* are Campgrounds and Lost World. Furious Heights has been playable publicly since *Quake Live* went into open beta in 2009 [9].



Figure 3.5: The three maps used throughout the scenarios.

3.2.2 Scenario Classifications

Each scenario was classified as either introductory, auditory-dependant, or visually-dependant. The introductory scenarios were intended to be straightforward, in order to act as a baseline and to give

participants the opportunity to familiarize themselves with the system. The auditory-dependant scenarios emphasized the need to listen and understand the auditory information or cues in the scenario to determine the opponent's location, while the visually-dependant scenarios emphasized the process of seeing and interpreting visual information or cues.

3.2.3 Scenario Descriptions

Scenario 1

- **Classification:** Introductory
- **Game Map Used:** Campgrounds
- **Duration:** 4 seconds

In this scenario, the point of view (POV) player can immediately both see and hear the opponent take a jump pad up to a higher level. Then the opponent can be heard moving (by jumping) along the upper level towards the POV player. The opponent comes into view and the POV player fires rockets from their rocket launcher weapon towards the opponent.

As an introductory scenario, it was intended to have a straightforward solution in order to familiarize participants with the system. As such, the opponent is visible at the end of the video.

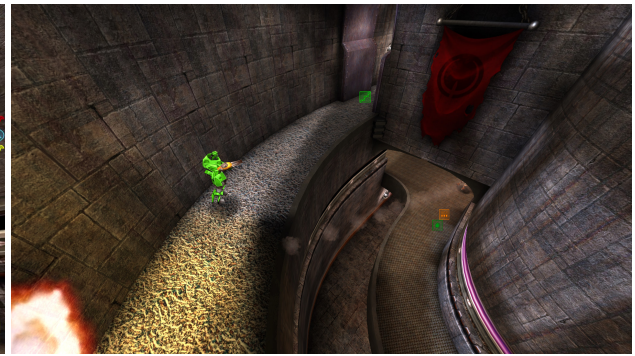
Scenario 2

- **Classification:** Introductory
- **Game Map Used:** Campgrounds
- **Duration:** 10 seconds

The POV player starts out on the upper ledge the opponent was on in Scenario 1. The POV player jumps down, walks under a bridge, and as they silently wait underneath they hear the opponent above switch weapons to the lightning gun with its audible buzz and then switch back to another silent weapon. The opponent can be heard walking on the bridge above. After a moment of silence, the POV player moves to the edge of the bridge, looks up, and sees the opponent above on the edge of the bridge.



(a) The final frame of the video.



(b) A third person view of the scenario.

Figure 3.6: The final frame of the video for Scenario 1 (a) and a third-person view of Scenario 1 (b), showing the opponent's final location.



Figure 3.7: The approximate paths the POV and opponent players took in Scenario 1.



(a) The final frame of the video.

(b) A third person view of the scenario.

Figure 3.8: The final frame of the video for Scenario 2 (a) and a third-person view of Scenario 2 (b), showing the opponent's final location.

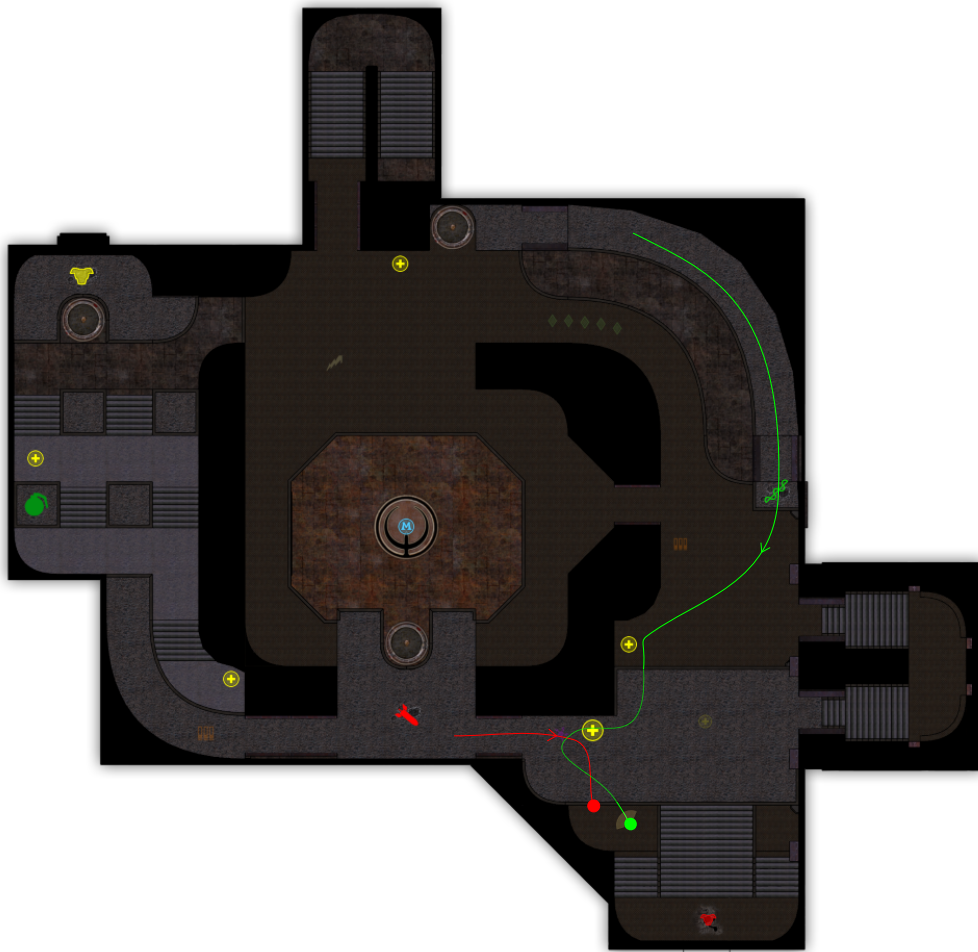


Figure 3.9: The approximate paths the POV and opponent players took in Scenario 2.

Once again, this introductory scenario has a straightforward solution as the opponent is visible at the end. The difference between this scenario and the first is that the enemy is only visible immediately at the end of the scenario and opponent enemy is closer.

Scenario 3

- **Classification:** Auditory-Dependent
- **Game Map Used:** Campgrounds
- **Duration:** 10 seconds

The POV player starts out on a lower level of the map and takes a jump pad up towards the rocket launcher. At the same time, the opponent is heard taking the jump pad on the opposite end of the map, towards the same upper ledge as in Scenario 1. The POV player then walks over the same bridge as described in Scenario 2 and jumps down towards where the red armour respawns. As the POV player is falling off the bridge, they look towards the upper ledge, and briefly (233ms; 7 frames at 30 frames per second) see the opponent standing on the ledge as the opponent is picking up and switching to the rail gun. As the video pauses, the hum of the rail gun can be heard.

One can pinpoint the opponent's location through the audiovisual cues that were both present and not present. In the order in which they are presented in the scenario, the first cue is the sound of the jump pad. This indicates the general area of the map the opponent is located in, and that they may be heading along the upper ledge towards the rail gun. Next is the brief sighting of the enemy and the simultaneously heard weapon pickup sound. This allows one to pinpoint the opponent's exact location seconds before the scenario ends, both visually, and audibly as one can connect the sound of the weapon pickup to the location of that weapon. Following this is the absence of movement sounds. This allows one to recognize that the opponent has not moved from the previously seen position. The final cue is the hum of the rail gun. This confirms the previous audiovisual cues heard and removes any doubt as to the opponent's location.



(a) The final frame of the video.

(b) A third person view of the scenario.

Figure 3.10: The final frame of the video for Scenario 3 (a) and a third-person view of Scenario 3 (b), showing the opponent's final location.

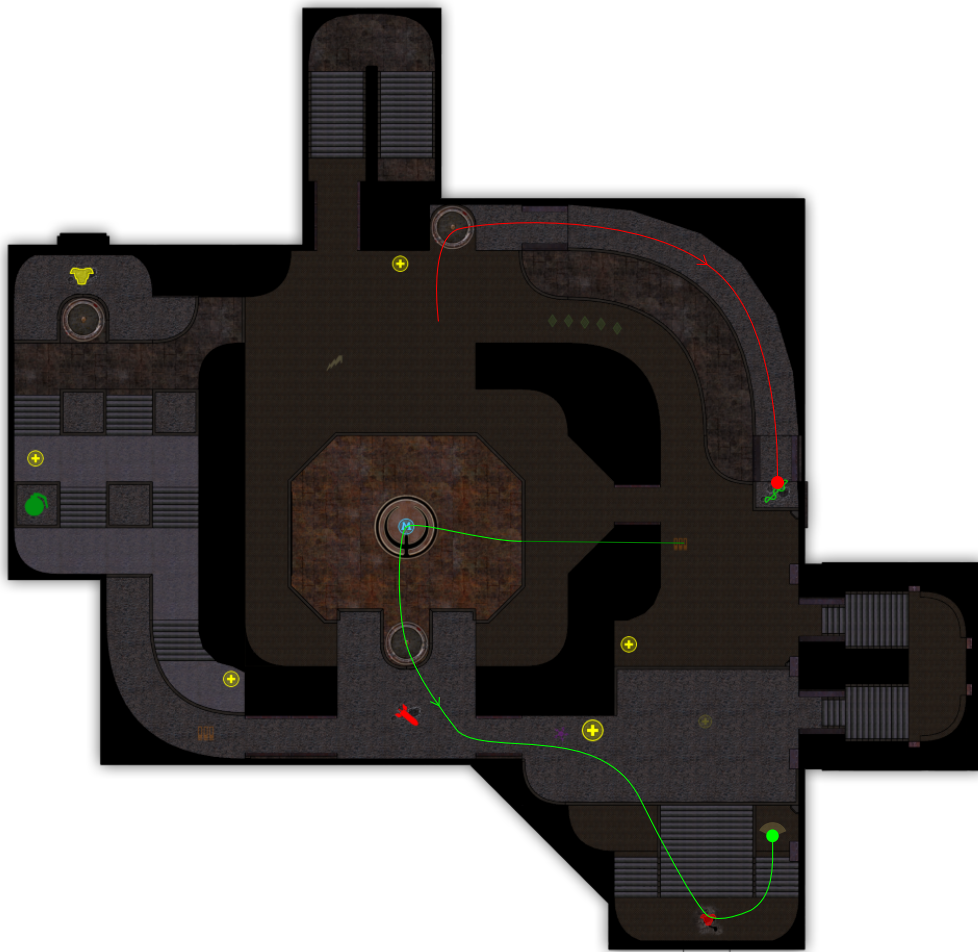


Figure 3.11: The approximate paths the POV and opponent players took in Scenario 3.

Scenario 4

- **Classification:** Visually-Dependent
- **Game Map Used:** Furious Heights
- **Duration:** 6 seconds

In the first second of this scenario, the POV player travels through a teleporter, which takes them to an upper level of the same room they were just in, and jumps across a gap, from one ledge to another. Immediately upon landing, the POV player looks through a doorway and notices rockets being fired in their direction through the long hallway. This continues for the remainder of the scenario.

One can estimate the opponent's location based on a combination of information. The most apparent cue is the direction of the rockets, this indicates that they must be coming from down the hallway. Next is the duration the rockets are in flight for. By recognizing that the initial firing sound of the rocket is not audible (only the sound in flight is), it's apparent that the opponent must be some distance away. Finally, the shallow angle of the rocket indicates that the opponent must be slightly above the POV player but somewhat far away.

Scenario 5

- **Classification:** Auditory-Dependent
- **Game Map Used:** Furious Heights
- **Duration:** 4 seconds

In this scenario, the POV player enters and walks through the hallway of the previous scenario, which the rockets were travelling through. As the player approaches the doorway at the end of the hallway, footsteps of the opponent are heard, followed by the sound of water splashing, jumping, and then the sound of the opponent entering and exiting the teleporter. One can know the opponent's exact location if they know where the teleporter exit is.



(a) The final frame of the video.



(b) A third person view of the scenario.

Figure 3.12: The final frame of the video for Scenario 4 (a) and a third-person view of Scenario 4 (b), showing the opponent's final location.



Figure 3.13: The approximate paths the POV and opponent players took in Scenario 4.



(a) The final frame of the video.



(b) A third person view of the scenario.

Figure 3.14: The final frame of the video for Scenario 5 (a) and a third-person view of Scenario 5 (b), showing the opponent's final location.



Figure 3.15: The approximate paths the POV and opponent players took in Scenario 5.

Scenario 6

- **Classification:** Visually-Dependent
- **Game Map Used:** Furious Heights
- **Duration:** 9 seconds

The POV player immediately drops down from a ledge onto a yellow armour, picks it up, and then heads through a teleporter back to the ledge they just dropped from. The player then jumps across a gap and lands on another ledge, runs through a doorway and encounters the opponent. The POV player lands a hit with the rail gun while the opponent deals a small amount of damage with the lightning gun. The POV player retreats through the doorway and then sees the opponent go through a different doorway and down a staircase. As the opponent escapes, they fire a number of defensive rockets in the direction they came from.

Much like Scenario 4, the rocket trail indicates the opponent's direction, but now one can estimate the opponent's distance travelled during the approximately two seconds that the opponent is not visible. Experts may also recognize that the opponent will be seeking out health and armour, and that the second yellow armour is available right as the video pauses. These cues all indicate that the opponent is running towards the yellow armour to pick it up.

Scenario 7

- **Classification:** Auditory-Dependent
- **Game Map Used:** Lost World
- **Duration:** 4 seconds

The POV player is on a lower level of the map moving silently towards a jump pad. He hears the opponent's footsteps and backs away from the jump pad in order to get out of sight. The opponent can then be heard jumping up to a ledge and picking up five armour shards. The sequential item pickup sounds reveal their location.



(a) The final frame of the video.

(b) A third person view of the scenario.

Figure 3.16: The final frame of the video for Scenario 6 (a) and a third-person view of Scenario 6 (b), showing the opponent's final location.

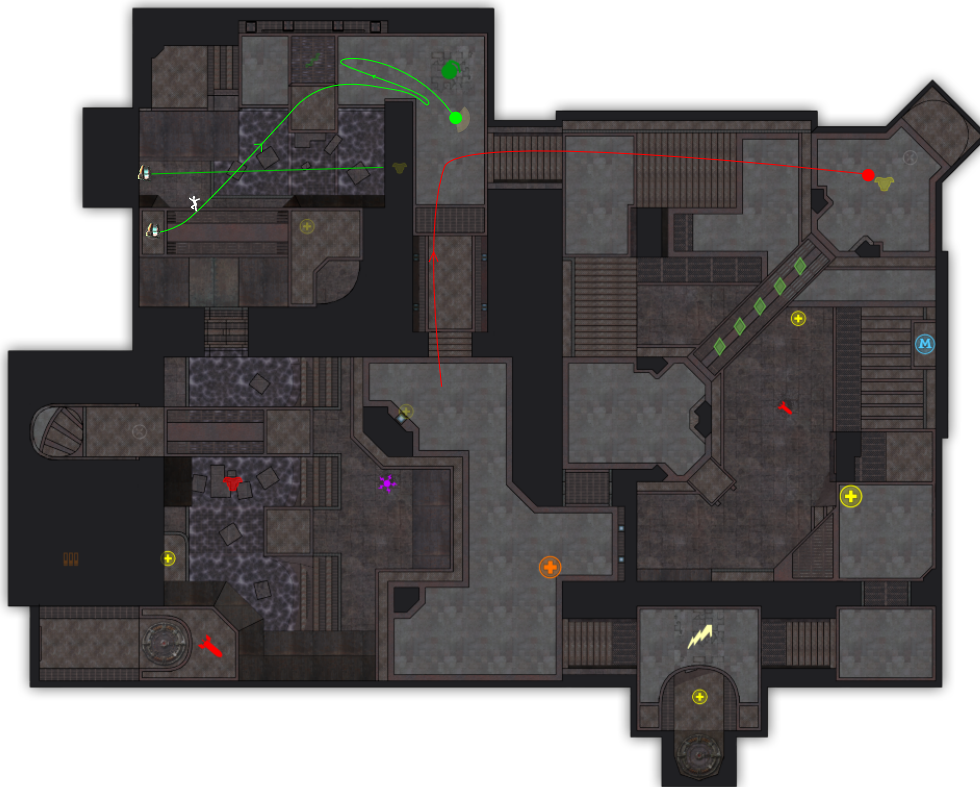
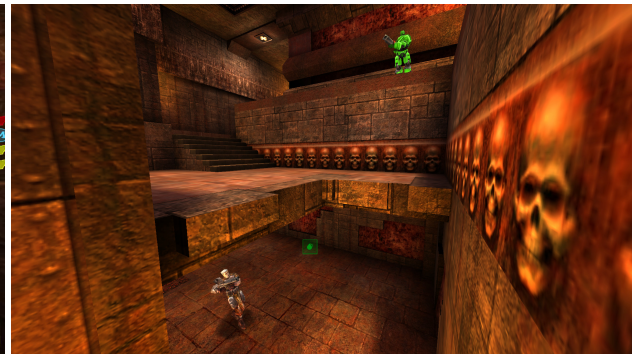


Figure 3.17: The approximate paths the POV and opponent players took in Scenario 6.



(a) The final frame of the video.

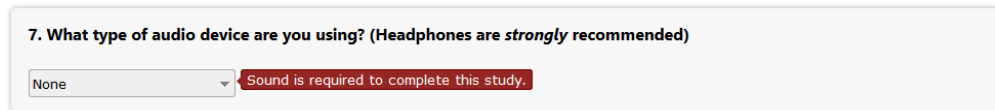


(b) A third person view of the scenario.

Figure 3.18: The final frame of the video for Scenario 7 (a) and a third-person view of Scenario 7 (b), showing the opponent's final location.



Figure 3.19: The approximate paths the POV and opponent players took in Scenario 7.

The image shows a survey question: "7. What type of audio device are you using? (Headphones are *strongly* recommended)". Below the question is a dropdown menu with "None" selected. To the right of the dropdown is a red error message that says "Sound is required to complete this study." data-bbox="190 88 799 140"/>

7. What type of audio device are you using? (Headphones are *strongly* recommended)

None Sound is required to complete this study.

Figure 3.20: What the user sees if they attempt to select that they have no sound.

3.3 Questionnaires

Each participant completed a questionnaire prior to the scenarios and another questionnaire after the scenarios.

For the demographics questionnaire, the following questions were asked:

- How many years have you been playing video games for?
- How many years have you been playing FPS games for?
- How many hours a week do you typically play video games in general (including FPS games)?
- How many hours a week do you typically play FPS games?
- How would you rate your expertise with FPS games in general?
- How would you rate your expertise with the games *Quake Live* or *Quake 3 Arena*?
- What type of audio device are you using? (Headphones are recommended)
- How old are you?
- What is your sex?

When selecting years, the available options were “less than 1 year,” “between 1 and 2 years,” “between 3 and 5 years,” “between 6 and 10 years,” and “over 10 years.” When selecting hours a week, the available options were “less than 1 hour,” “between 1 and 2 hours,” “between 3 and 5 hours,” “between 6 and 10 hours,” and “over 10 hours.” When selecting expertise, the available options were “novice,” “experienced,” and “expert.” For the audio device selection, the shown options were “headphones,” “speakers,” and “none.” Users who selected “none” were informed that sound is required to complete the study, as shown in Figure 3.20.

For the post-scenarios questionnaire, the following questions were asked:

- On a 5 point scale from “Not Important” to “Very Important”:
 - How important is it to know where your enemies are?
 - How important is knowledge of a specific game (e.g. *Quake Live*) when locating other players?
 - How important is knowledge of the specific map or level (including layout, item locations, etc.) when locating other players?
- On a 5 point scale from “Very Easy” to “Very Difficult”:
 - How difficult was it to get an idea of where the other player was?
 - How difficult was it to describe with words where the other player was?
 - How difficult was it to point out where the other player was on a map?
 - How difficult was it to name the cues (sounds, visual information, etc.) that helped you know where the other player was?
 - How difficult was it to connect sounds to specific objects in the game?
 - How difficult was it to connect sounds to locations on the map?
 - How difficult was it to understand what was happening in the videos?
- As open text field responses:
 - Of the cues (sounds, visual information, etc.) you noted, which ones do you think were the most important?
 - Do you have any additional comments?

3.4 Performance Review

After completing all of scenarios and filling out the final questionnaire, the user had the opportunity to review their performance (Figure 3.21). The solutions to each scenario were shown alongside the user’s location estimate and the cues they listed. Additionally, for each scenario the video could be reviewed, a third-person image showing the location of both players could be viewed, and an overview of how the correct location could be estimated was provided.

Thanks for participating! Here are your results.



Figure 3.21: The performance review.

3.5 Technical Implementation

The system was implemented using web-based technologies so it could be deployed online. The system was built as a Flask¹ app, using Python 2.7 and Flask 0.10.x. A database connection and programming interface (using an object-relational mapper) was built using SQLALchemy², using the Flask extension Flask-SQLALchemy.

The user interface was developed using the JQuery UI framework JQWidgets³, which provided a consistent and modern look and feel, as well as client-side form validation. To view the videos, JW Player⁴ was used – this allowed for logging of detailed playback data to see how long each participant viewed each video. The clickable 2D map required the usage of HTML5's canvas. The JCanvas API⁵ was used to facilitate this.

The video scenarios were recorded at a resolution of 1280x720, at 30 frames per second and a constant bitrate of 4000 kbps. The open-source *Quake Live* demo (or replay) playback tool, WolfcamQL was used to playback select replays, which were then recorded using Open Broadcaster Software.

The map images were generated by modifying the BSP (binary space partitioning) map files that were shipped with *Quake Live*. The process of extracting the BSP file from the files shipped with the game and converting is described in detail on a community forum⁶. The instructions were followed to create a .map file, which was then opened in the map editor GtkRadiant 1.6.4. The geometry of the map was simplified by cutting away the upper-most portions of the map, as shown in Figure 3.22. After completing this, the map as viewed from the top was much clearer. The final images, as shown in Figure 3.5, were created after some image editing done using Adobe Fireworks. At this point, icon representations of the icons were added to the image.

¹<http://flask.pocoo.org/>

²<http://www.sqlalchemy.org/>

³<http://www.jqwidgets.com/>

⁴<http://www.jwplayer.com/>

⁵<http://projects.calebevans.me/jcanvas/>

⁶<http://www.esreality.com/post/2221321/how-to-export-ql-maps-to-3d-format/>

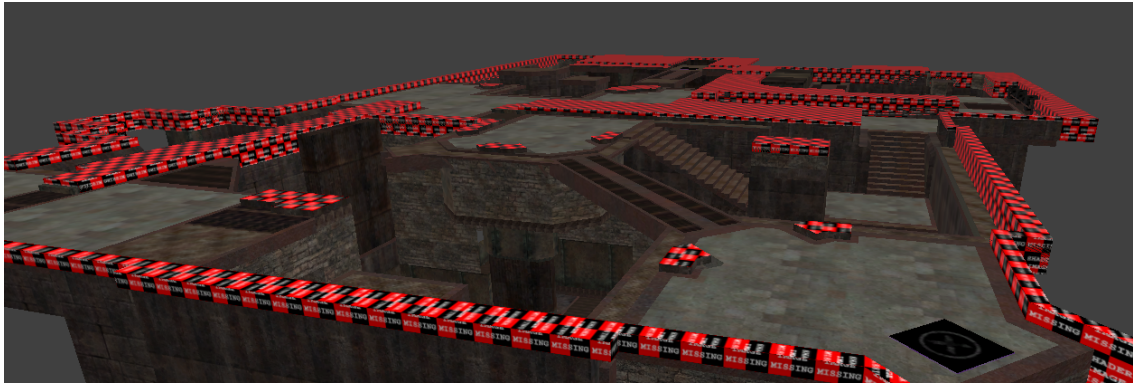


Figure 3.22: The result of cutting away the top portions of the map, for the map “Furious Heights.”

CHAPTER 4

DETERMINING EXPERT STRATEGIES (STUDY 1)

The first study was conducted because we were interested in determining the strategies that experts use to locate other players. This was our primary goal. Our expectation was that the strategies they used would differ depending on the conditions they were presented with. A secondary goal was to verify that novices don't also apply these strategies – something we believed to be true but wanted to confirm. The previously described system in Chapter 3 was utilized in order to answer these questions.

4.1 Procedure

After providing informed consent, participants completed a demographics questionnaire regarding their overall gaming history, gaming frequency, FPS expertise, sex, and age. Expertise level was self-rated, from novice, experienced, or expert, and was collected for both FPS games in general and for *Quake Live* specifically. Following this, participants were given instructions to introduce them to the game's heads-up display (HUD) and how to read the top-down 2D maps that are used throughout the study. After this, participants begin to go through the procedure of watching and responding to the video scenarios, as described in Chapter 3. The last steps were the final questionnaire and the performance review, both of which are also described in Chapter 3.

4.2 Participants and Recruitment

We were interested in reaching out primarily to experts of the genre, and specifically to experts of the game, in order to verify their performance and determine the strategies they used to locate the opponent in each scenario. The study was advertised in part as a way of improving one's ability

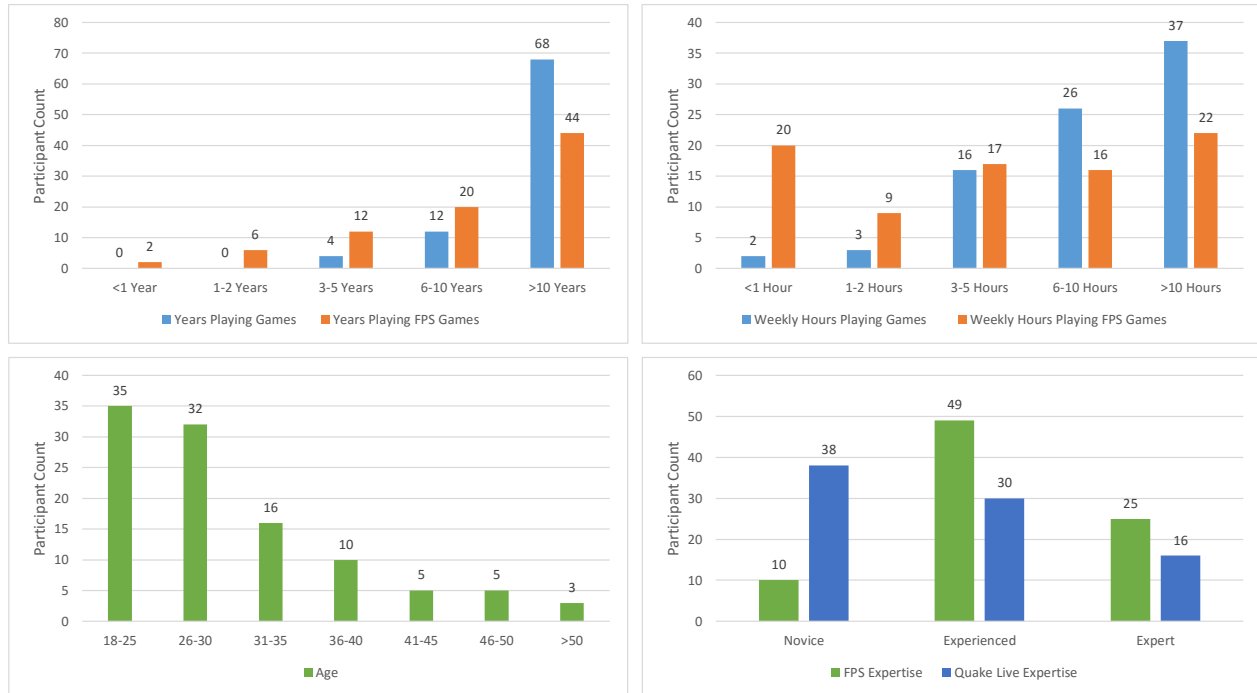


Figure 4.1: Demographics for Study 1.

to locate opponents in a game via the performance review at the end of the study (see Section 3.4). Advertising was done a a variety of online sources, including gaming community forums, re-tweets on Twitter (in particular, one by the @QuakeLive account going out to over 28,000 of their followers), sharing on Facebook, and the University of Saskatchewan’s online bulletin board. This variety in advertising sources led to both experts in the genre as well as novices to participate in the study.

We had 92 participants complete the study. Of those, 8 were excluded from the analysis for not watching the videos to completion, leaving 84 participants. All participants were over the age of 18, with the majority being aged between 18 and 25. Grouping the participants by *Quake Live* expertise, 38 (45.2%) self-identified as novice, 30 (35.7%) as experienced, and 16 (19%) as expert. The complete demographics information is in Figure 4.1.

4.3 Scenarios

We looked at individual scenarios, as well as scenarios grouped by their classification, which was based on the type of cue that was primarily responsible for revealing the opponent’s location (in-

troductory, visually-dependant, or auditory-dependant).

4.3.1 Data Analyses

To determine the accuracy differences between expertise groups, we present heatmaps of the location responses. The heatmaps are based on kernel-density estimation, as described by Lampe et al. [41]. We also examined the written location responses, looking for patterns of similar responses that might indicate a common strategy for locating opponents.

For each scenario or scenario group, we also present the descriptive statistics for the following metrics:

- *Guess Counts*: Count of whether or not participants chose to make a location guess for each scenario in the group, represented as a percentage of the total number of possible guesses, to accommodate different expertise group sizes.
- *Confidence Rating*: Participant confidence in their guesses collected using a 5-pt scale (5 is more confident).
- *Cue Counts*: Count of identified cues prefixed with “I saw,” or “I heard,” represented as an average of counts over the scenarios in the group.

For the scenario groups only, to compare the performance of the expertise groups, we conducted a one-way analysis of variance (ANOVA) on confidence ratings for each scenario type separately, using pairwise comparisons (least significant different) to examine differences between the expertise groups. For the guess and cue counts, which do not meet the assumptions of ANOVA, we used the nonparametric Kruskal-Wallis test, with the Mann-Whitney U for pairwise comparison [19]. An alpha level of 0.05 was used for all statistical tests.

4.3.2 Individual Scenario Results

The descriptive statistics for each scenario are presented in Table 4.1. Aside from the straightforward introductory scenarios, the scenarios were chosen to emphasize either the need to listen and understand the auditory information and cues (auditory-dependant), or emphasize the need to see and interpret visual information and cues (visually-dependant).

		Number of Guesses	Confidence Rating	Number of “I Saw” Responses	Number of “I Heard” Responses
Scenario 1 Introductory	Expert	1.00 (0.00)	4.94 (0.25)	1.13 (0.34)	1.19 (0.98)
	Experienced	0.93 (0.25)	4.80 (0.81)	1.03 (0.32)	1.03 (0.85)
	Novice	0.95 (0.23)	4.18 (1.23)	1.18 (0.56)	0.37 (0.68)
Scenario 2 Introductory	Expert	1.00 (0.00)	5.00 (0.00)	0.94 (0.25)	0.81 (0.66)
	Experienced	0.97 (0.18)	4.87 (0.73)	0.83 (0.38)	1.17 (0.75)
	Novice	0.95 (0.23)	4.66 (0.94)	0.89 (0.51)	0.89 (0.61)
Scenario 3 Auditory	Expert	1.00 (0.00)	4.88 (0.34)	0.63 (0.62)	2.31 (1.20)
	Experienced	0.93 (0.25)	4.63 (1.07)	0.53 (0.51)	2.50 (0.94)
	Novice	0.61 (0.50)	2.68 (1.53)	0.34 (0.48)	1.08 (0.94)
Scenario 4 Visual	Expert	1.00 (0.00)	4.38 (0.72)	0.69 (0.48)	0.44 (0.51)
	Experienced	0.97 (0.18)	4.13 (0.90)	0.50 (0.51)	0.60 (0.56)
	Novice	0.87 (0.34)	3.76 (1.26)	0.68 (0.53)	0.21 (0.41)
Scenario 5 Auditory	Expert	1.00 (0.00)	4.88 (0.50)	0.00 (0.00)	2.63 (1.09)
	Experienced	0.93 (0.25)	4.40 (1.16)	0.00 (0.00)	2.27 (1.39)
	Novice	0.76 (0.43)	2.68 (1.34)	0.03 (0.16)	1.55 (1.13)
Scenario 6 Visual	Expert	1.00 (0.00)	4.25 (0.78)	1.06 (0.77)	0.81 (0.75)
	Experienced	0.87 (0.35)	4.10 (1.21)	0.80 (0.66)	1.03 (0.93)
	Novice	0.92 (0.27)	4.26 (1.18)	1.32 (0.66)	0.84 (0.95)
Scenario 7 Auditory	Expert	1.00 (0.00)	5.00 (0.00)	0.00 (0.00)	2.19 (0.66)
	Experienced	0.97 (0.18)	4.67 (0.84)	0.00 (0.00)	2.03 (0.85)
	Novice	0.68 (0.47)	2.82 (1.13)	0.05 (0.23)	1.55 (0.80)

Table 4.1: Descriptive statistics results for each scenario, compared between self-rated *Quake Live* expertise. Numbers in brackets indicate standard deviation.

		Number of Guesses	Confidence Rating	Number of “I Saw” Responses	Number of “I Heard” Responses
Introductory	Expert	1.00 (.00)	4.97 (.13)	1.0 (.22)	1.0 (.73)
	Experienced	0.95 (.20)	4.95 (.20)	0.9 (.29)	1.1 (.65)
	Novice	0.95 (.23)	4.41 (.71)	1.0 (.44)	0.6 (.49)
Visual	Expert	1.00 (.00)	4.16 (.63)	0.9 (.56)	0.6 (.47)
	Experienced	0.92 (.23)	4.05 (.63)	0.7 (.49)	0.8 (.66)
	Novice	0.89 (.29)	4.13 (.73)	1.0 (.51)	0.5 (.58)
Auditory	Expert	1.00 (.00)	4.92 (.19)	0.2 (.21)	2.4 (.75)
	Experienced	0.94 (.20)	4.61 (.66)	0.2 (.17)	2.3 (.75)
	Novice	0.68 (.39)	2.89 (.92)	0.1 (.17)	1.4 (.77)

Table 4.2: Descriptive statistics results for the scenario groups, compared between self-rated *Quake Live* expertise. Numbers in brackets indicate standard deviation.

Upon evaluating the descriptive statistics, it became clear that the scenario classification played an important role. Although the experts were consistent with their guess count and confidence across every scenario, the novices were not. Their visually-dependant scenarios resulted in a higher number of guesses (0.89 overall) and a higher confidence rating (4.13 overall) when compared to the auditory-dependant scenarios (0.68 overall for guesses and 2.89 overall for confidence). Similar patterns also exist for the cue counts.

With this in mind, in order to reduce the repetitiveness of the analysis, we decided to consider the scenarios as grouped by their classification.

4.3.3 Grouped Scenario Results

Introductory Scenarios

Within the introductory scenarios, expertise did not yield a significant difference in guess counts ($\chi^2_2 = 1.03$, $p = .596$).

There was a difference in the confidence of guesses based on expertise ($F_{2,81} = 3.7$, $p = .029$). Post-hoc tests revealed that novices were less confident than experienced ($p = .035$) or expert ($p = .022$) players; there was no observed difference between experienced and expert players ($p = .580$).

There was a difference in the number of audio cues used, depending on expertise ($\chi^2_2 = 9.52$, $p = .009$); novices used fewer audio cues than experienced players ($p = .003$) and marginally fewer than expert players ($p = .055$). There was no observed difference between experienced and expert players ($p = .630$). There was no observed difference in the number of visual cues used by

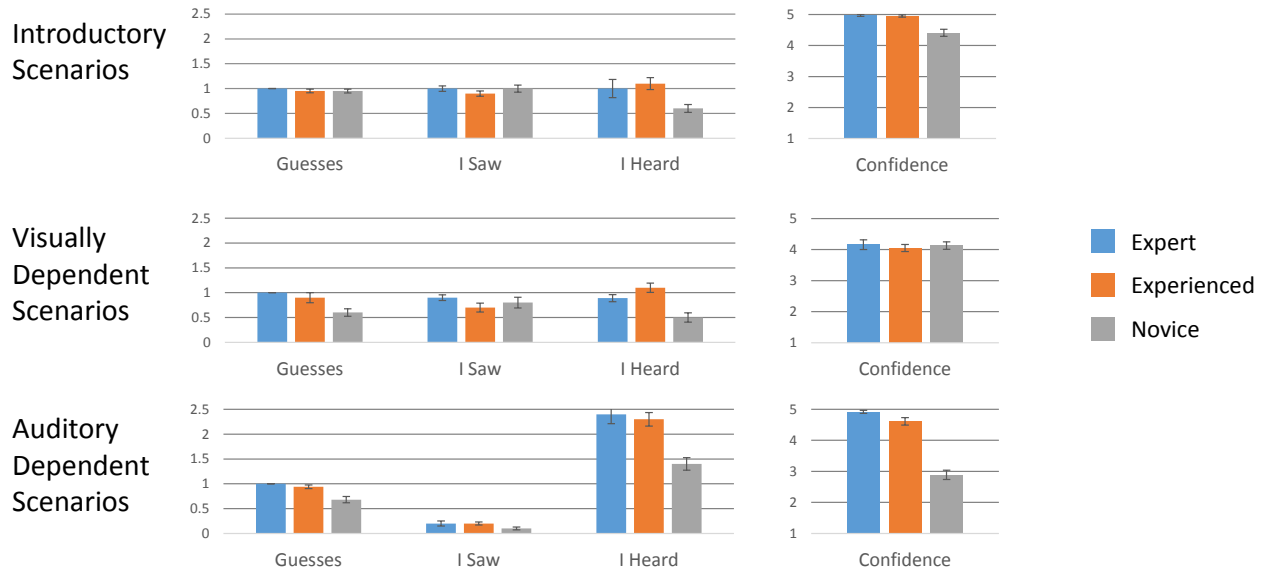


Figure 4.2: Charts of the descriptive statistic results for the scenario groups, compared between self-rated *Quake Live* expertise. Error bars are standard error.

expertise ($\chi^2_2 = 1.18, p = .553$).



The heatmaps (Figure 4.3) show that nearly all participants chose the correct location, with the possible exception of some novices being slightly inaccurate in response to the first scenario.

Visually-Dependant Scenarios

In the visual scenarios, expertise did not yield a significant difference in the number of guesses ($\chi^2_2 = 2.34, p = .331$), or in the confidence of the guesses ($F_{2,81} = 0.55, p = .579$).

There was no significant difference in the number of audio cues used, based on expertise ($\chi^2_2 = 3.7, p = .156$). There was, however, a difference in the number of visual cues used based on expertise ($\chi^2_2 = 7.275, p = .026$), in which novices listed more visual cues than experienced ($p = .022$), but not expert ($p = .99$) players; there was no observed difference between expert and experienced players ($p = .457$).

The heatmaps (Figure 4.4) show a difference in the pattern of the location guesses, in which novices tended to underestimate the opponent's distance, though they understood the correct direction. On scenario 4, expert players tended to overestimate the opponent's location. Some of their reasons indicated the strategic importance of a player positioning themselves in a way that makes it easy to pick up the lower red armour or falling back to the health pack if they take damage.

 Opponent's Actual Location
 Point of View Player's Location

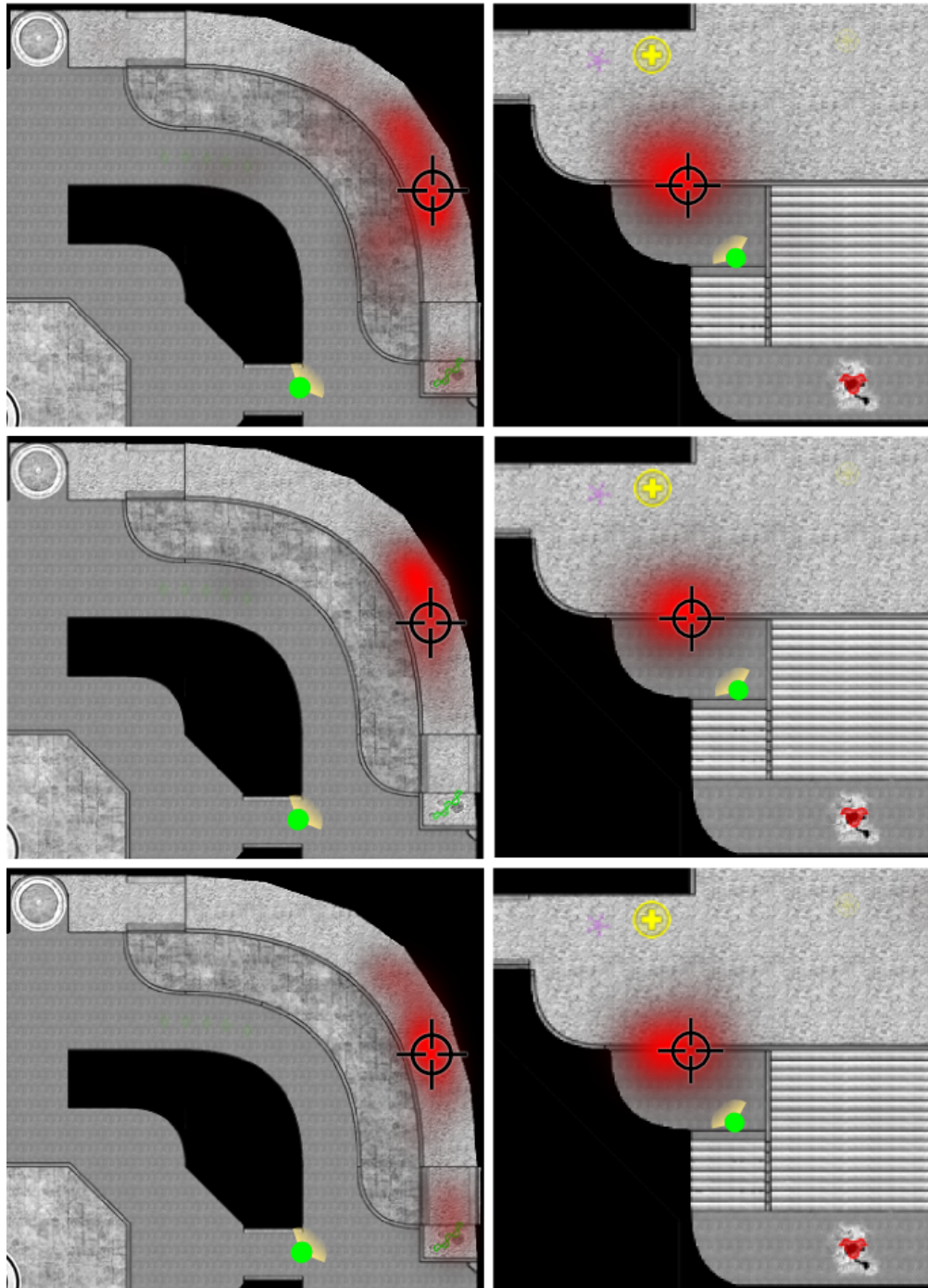


Figure 4.3: Heatmap of location responses for the introductory scenarios. The first column is scenario 1, the second is scenario 2. The rows are, from top to bottom, novice, experienced, and expert. The reticle indicates the opponent's location and the green circle indicates the point-of-view (POV) player's location.



Figure 4.4: Heatmap of location responses for the visually-dependant scenarios. The left column scenario 4, the right is scenario 6. The rows are from top to bottom, novice, experienced, and expert. The reticle indicates the opponent's location and the POV player's location is in green.

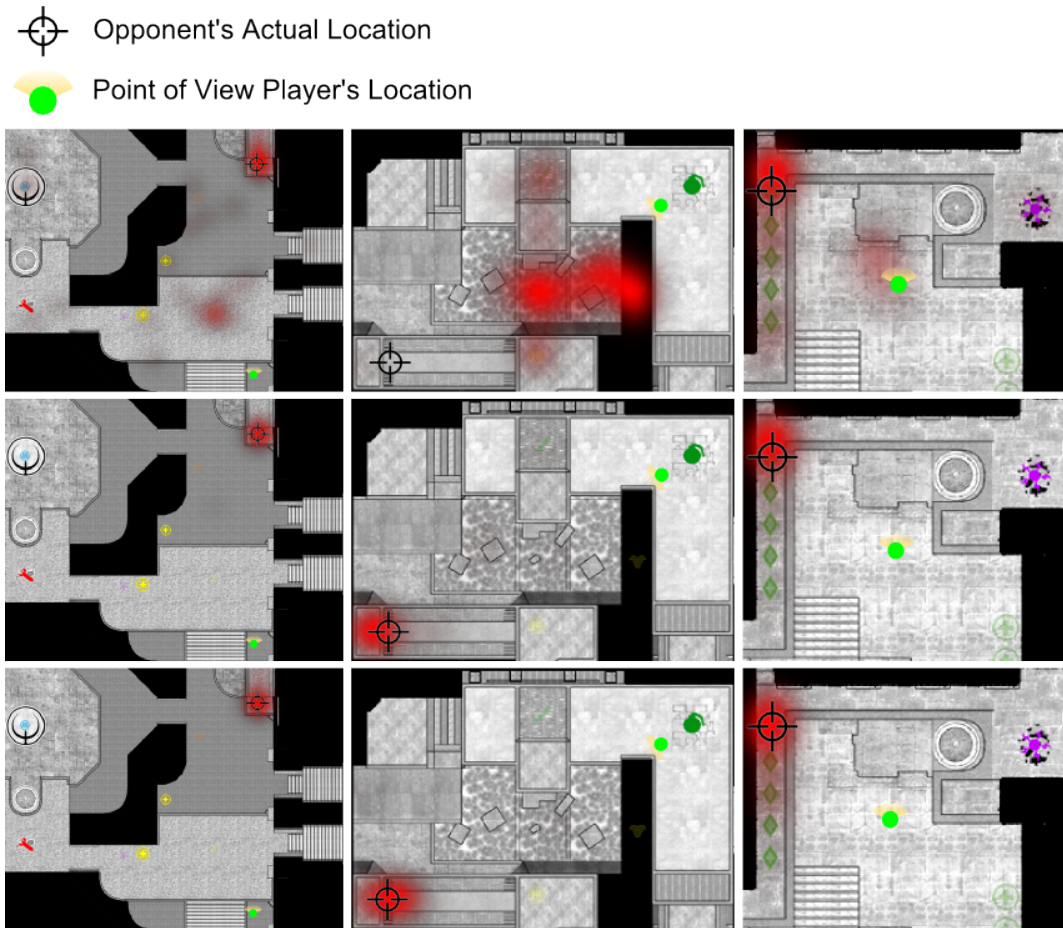


Figure 4.5: Heatmap of location responses for the auditory-dependant scenarios. From left to right, scenario 3, scenario 5, and scenario 7. From top to bottom, novice, experienced, and expert. The reticle indicates the opponent's location and the POV player's location is in green.

For the written responses of scenario 6, containing the respawning yellow armour, many expert (75.0%) and experienced (60.0%) participants mentioned how the opponent was heading towards the yellow armour, while few (5.3%) novices did. Scenario 4 did not have any landmarks that participants could utilize to precisely locate the opponent.

Auditory-Dependant Scenarios

Within the three auditory scenarios, there was a significant difference in the number of guesses based on expertise ($\chi^2_2 = 18.9, p < .001$); novices made fewer guesses than both experts ($p < .001$) and experienced players ($p < .001$). There was no observed difference between experienced and expert players ($p = .483$).

There was a difference in the confidence of guesses based on expertise ($F_{2,81} = 41.8, p < .001$); novices were less confident than both experienced ($p < .001$) and expert ($p < .001$) players. There was no observed difference between expert and experienced players ($p = .255$).

There was a difference in the number of audio cues used, depending on expertise ($\chi^2_2 = 23.3, p < .001$); novices used fewer audio cues than experienced ($p < .001$) or expert ($p < .001$) players. There was no observed difference between experienced and expert players ($p = .623$). There was no significant difference in the number of visual cues used ($\chi^2_2 = 1.55, p = .460$).

There were also differences in the pattern of location guesses, as seen in the heatmap (Figure 4.5). In scenario 3, novices sometimes failed to recognize the item pickup sound, which placed the opponent at the railgun location. In scenario 5, novices failed to connect the sound of the teleporter to the opponent's location, and instead guessed that the opponent was in the water. Expert and experienced players had no issue identifying the teleporter exit location and specifying that the opponent was there. In scenario 7, novices were often able to identify the opponent's location; however, some did still choose an incorrect location.

Written responses from experts tended to describe the other player's location based on the origin of the last sound they heard. For example, in scenario 5, the one in which the opponent was near the armour shards, the majority of expert (93.8%) and experienced (80.0%) players described the other player's location as being near the armour shards, whereas novices (10.5%) tended not to. The same pattern exists for the other two scenarios in this group and overall, most expert (91.7%) and experienced (75.6%) players made note of the revealing cue to determine the opponent's location describing the opponent as being near the rail gun, teleporter exit, or armour shards due to the associated audio cue they heard, whereas novices (5.3%) did not. The heatmaps (Figure 4.5) confirm how this approach allowed participants to locate the opponent.

4.4 Questionnaire

4.4.1 Data Analyses

To compare the importance and difficulty ratings between expertise groups, we present the descriptive statistics. We also conducted a one-way analysis of variance (ANOVA) on the ratings

Question	Novice	Experienced	Expert	$F_{2,81}$	p
1. How important is it to know where your enemies are?	4.82 (0.39)	4.70 (0.70)	4.94 (0.25)	1.182	.312
2. How important is knowledge of a specific game when locating other players?	4.42 (0.76)	4.40 (0.86)	4.25 (1.07)	0.236	.790
3. How important is knowledge of the specific map or level when locating other players?	4.42 (0.92)	4.60 (1.04)	4.62 (0.72)	0.426	.654
4. How difficult was it to get an idea of where the other player was?	2.74 (0.92)	1.97 (0.72)	1.44 (0.63)	16.320	<.001
5. How difficult was it to describe with words where the other player was?	3.16 (1.39)	2.47 (1.20)	1.44 (0.63)	11.611	<.001
6. How difficult was it to point out where the other player was on a map?	2.39 (0.82)	1.70 (0.75)	1.25 (0.45)	15.690	<.001
7. How difficult was it to name the cues that helped you know where the other player was?	2.58 (1.33)	1.90 (0.92)	1.31 (0.70)	8.249	.001
8. How difficult was it to connect sounds to specific objects in the game?	3.05 (1.39)	1.27 (0.45)	1.06 (0.25)	37.152	<.001
9. How difficult was it to connect sounds to locations on the map?	3.29 (1.27)	2.00 (1.11)	1.88 (0.81)	14.247	<.001
10. How difficult was it to understand what was happening in the videos?	2.05 (1.01)	1.43 (0.68)	1.19 (0.40)	8.272	.001

Table 4.3: Results for the questionnaire, including the descriptive statistics compared between self-rated *Quake Live* expertise and the results of the one-way ANOVA. Numbers in brackets indicate standard deviation.

separately for each question, using pairwise comparisons (least significant different) to examine differences between the expertise groups.

4.4.2 Results

The questions, and the descriptive statistics for each question, compared between expertise groups, are shown in Table 4.3. The same table also shows the results of the one-way ANOVA.

For all three questions rating importance, there was no observed difference between the expertise groups (see Table 4.3), meaning that all participants agreed on the importance of the tasks.

For the seven remaining questions rating the difficulty of aspects of the task of locating opponents, there were significant differences in the difficulty ratings based on expertise for every question (see Table 4.3).

Post-hoc tests revealed that novices found all of the tasks more difficult than both experienced and expert players (see Table 4.4). Experienced players found the tasks of getting an idea where the opponent was and describing this location in words to be more difficult than the expert players.

Question	Novice-Experienced	Novice-Expert	Experienced-Expert
4.	$p<.001$	$p<.001$	$p=.040$
5.	$p=.022$	$p<.001$	$p=.007$
6.	$p<.001$	$p<.001$	$p=0.53$
7.	$p=.013$	$p<.001$	$p=.087$
8.	$p<.001$	$p<.001$	$p=.505$
9.	$p<.001$	$p<.001$	$p=.724$
10.	$p=.003$	$p<.001$	$p=.332$

Table 4.4: Post-hoc test results for the questionnaire, comparing between self-rated *Quake Live* expertise.

There was no difference for questions 6 to 10.

These results can be summarized by stating that experts were in complete agreement as to how easy the task was for them – they found every aspect of the task, described by questions 4 to 10, to be easy compared to novices and in some cases, experienced players. All expertise groups were in agreement as to the important of the task, rating it quite high in importance.

4.4.3 The Importance of the Cues

As part of the final questionnaire, we asked participants, “of the cues (sounds, visual information, etc.) you noticed, which ones did you think were the most important?” The responses we received were interesting, and many participants ranked the importance in some way. The way in which they ranked them seems to depend on their interpretation of what “important” referred to. For example, consider these two examples:

1. “Sounds are very important, but I think visual information such as seeing rockets being spammed or the direction a player was heading are slightly more important.”
2. “Sound, item pickup sound as it can give a very exact location, followed by visualization of weapons fire (rocket trajectories in this case) when a player is not within sight.”

The first example seems to be from the perspective that “importance” refers to how threatening the awareness cue is. The more the awareness cue indicates the possibility of danger, the more important it is. The participant of the second example seems to believe that “importance” refers to how revealing the awareness cue is. This trend is seen throughout the responses:

- Threat or danger examples

- “In order: 1) Visually seeing the player 2) Footsteps/Jumping 3) Item pickup sounds are useful if you know where they’re located and if you’re quick to react.”
- “clearly visual acquisition of enemy is the most important. Sound is a close second - in particular patterns of sounds. e.g. strafe jumps followed by an item pickup.”
- Revealing information examples
 - “Unique sounds like jump pads and items help pinpoint. Other sounds only give general location.”
 - “Visual information is usually the most accurate, but when that is not available, sound cues are necessary to figuring out the opponent’s location.”
 - “visual was the most useful to me. But if I could identify the sounds and their locations on the map they could be very useful”

On the “threat or danger” side, there was unanimous agreement about visual cues being the most important, however, on the “revealing information” side, there wasn’t. Participants didn’t agree about whether visual cues or auditory cues were most important. The last example hints at why this may be the case – leveraging the auditory cues relies on knowledge that the participant may not have, depending on their familiarity with the game, while visual cues are more accessible.

4.5 Summary

With Study 1, we had two goals: First, determine how experts locate opponents, and second, verify that this skill is something novices do indeed struggle with. We achieved the first goal by gathering information about the audiovisual awareness cues experts use to solve scenarios that we believed to have specific solutions involving the use of those cues. We achieved the second goal by testing both novices and experts and comparing between the two groups.

Specifically, we designed a system that involved having participants watch and respond to video scenarios of common in-game situations. They were asked to try to locate the opposing player at the end of the video scenario and list the cues they used to do so. Recruiting from a variety of sources allowed us to reach participants with a wide range of backgrounds and expertise levels.

In analyzing the data, we grouped the responses by the type of awareness cue that was primarily responsible for revealing the opposing player's location. For the introductory scenarios, we found that novices were less confident in their guesses and listed fewer audio cues than either experienced or expert players.

For the visually-dependant scenarios, we found that novices listed more visual cues than experienced but not expert players. The more surprising result is that novices guessed just as often and were just as confident as either experienced or expert players. They also were able to determine the opposing player's correct direction, although they underestimated the distance.

Finally, for the auditory-dependant scenarios, we found that novices made fewer guesses, had less confidence, and listed fewer audio cues than either experienced or expert players. There were no observed differences between experienced and expert players. We found that these differences also translated into differences in the accuracy of their location guesses; experts overwhelmingly indicated the correct location, whereas novices tended to choose an incorrect location.

The questionnaire provides further evidence for the differences between novices and experts. On all questionnaire questions relating to the difficulty of different tasks, novices rated them as being significantly more difficult for them than either the experienced or expert players.

Arguably the most revealing result of Study 1 was that novices are almost universally unable to leverage the information provided by auditory awareness cues. When an understanding of these cues was a requirement for determining the opponent's location, novices made fewer guesses, had less confidence, identified fewer cues, and had poor accuracy. Comparing this to visually-dependent scenarios, novices only listed fewer visual cues – they still made just as many guesses and had just as much confidence as either experienced or expert players. It is for these reasons that we focused our efforts on developing scaffolding systems to help novices leverage the use of auditory awareness cues for locating opponents.

CHAPTER 5

SCAFFOLDING SYSTEMS

We designed two separate scaffolding systems to introduce novices to the concept of using audio cues for location awareness of opponents, a modified in-game interface, and a training system.

5.1 Modified In-Game Interface

In digital games, a heads-up display is a type of in-game interface which is used to display information to the player [80]. In first-person shooters, it is typically displayed persistently and contains information such as a player's current health, armour, weapons, and ammunition.

In Study 1, we observed that the confidence levels of novices increased whenever visual cues were present and that visual cues were recognized more often. Additionally, we came across game accessibility research on using redundant visual information to represent sounds for hearing impaired gamers [34, 48]. Our observations combined with this previous accessibility research inspired us to create a modified game interface that would visually call attention to audio cues which were heard.

Our approach was implemented by modifying the open-source *Quake Live* demo playback tool, WolfcamQL. A region on the bottom right was added to the HUD to show visual representations of the audio cues that were heard (see Figure 5.1). For example, if the opposing player jumped, an icon representing the jump action was shown on the HUD. The possible icons are shown in Figure 5.2.

The addition of the HUD icons don't reveal any additional information that wasn't already present, particularly for those players who have mastered the skill of understanding and leveraging audio cues. However, our intention was simply to highlight the presence of these cues so that novices may begin to consider their importance.

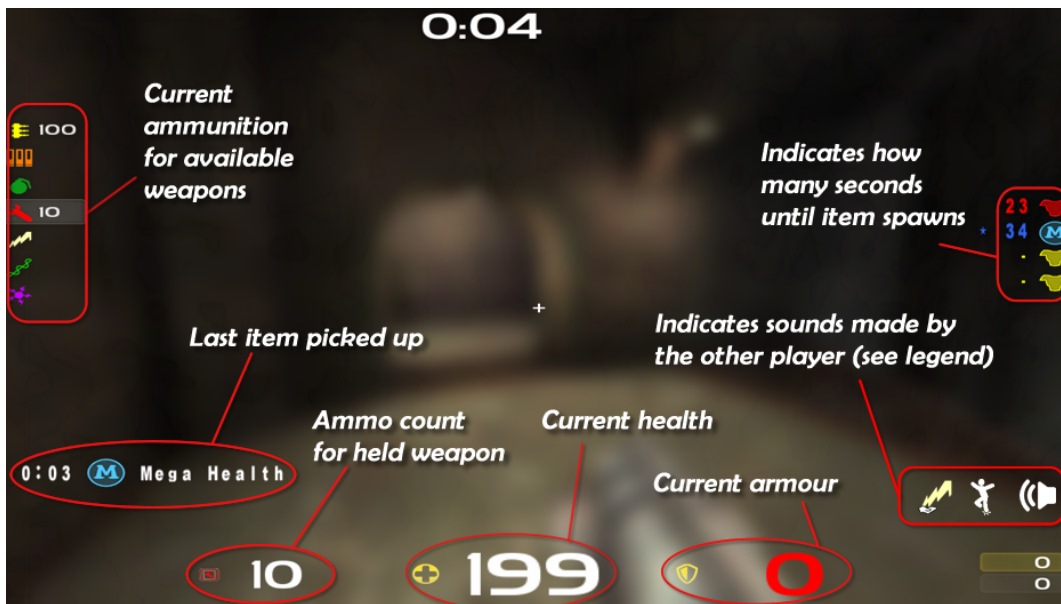











Figure 5.1: The modified in-game HUD interface.

The other player...

	is jumping		is walking
	switched weapons		touched water
	fired their rocket launcher		had a rocket explode*
	stepped on a jump pad		picked up the red armor
			went through a teleporter*

*Icon appears for your actions as well

Note: Some icons from Freepik (freepik.com)

Figure 5.2: The icons representations on the sound that appeared on the HUD.

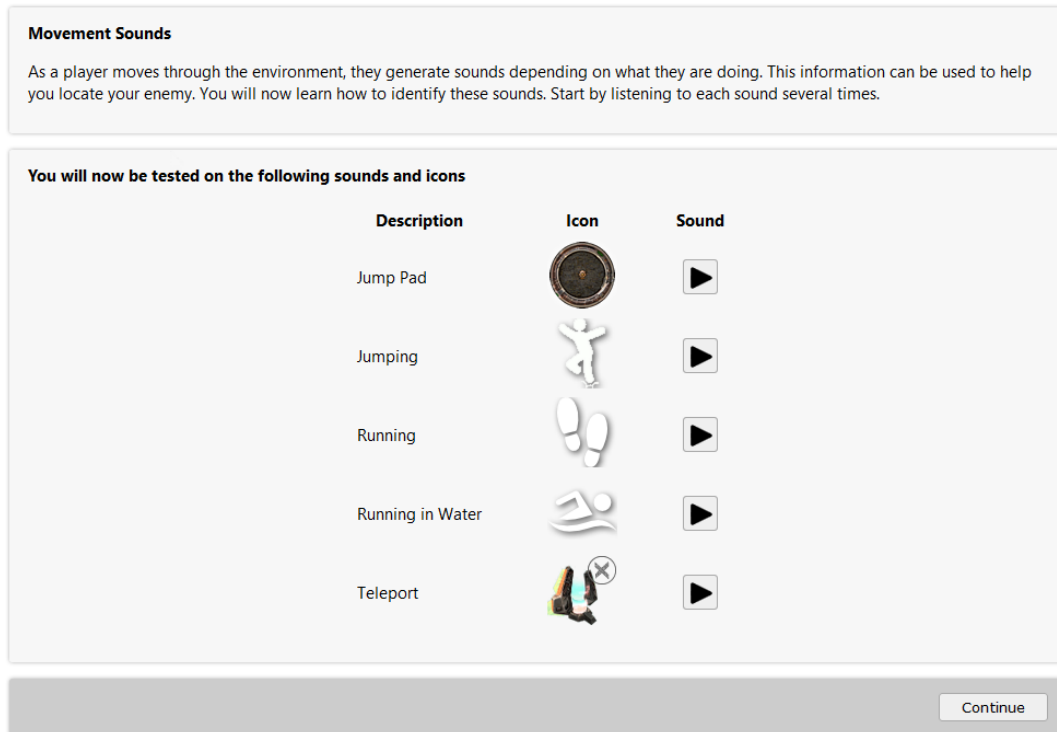


Figure 5.3: Before training on each set of cues, a brief introduction was shown, and the user could optionally listen to the sounds.

5.2 Training System

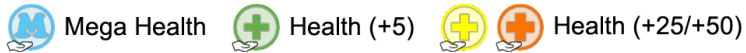
For our second scaffolding system, we created a training system that was external to the game. That the system was external to the game wasn’t necessarily a design choice; it was mainly due to technical limitations, as we could not modify the game. The point of the system was to teach the sounds that are heard in the game so that they could be distinguished from each other and recognized. From this, our hope was that players would be able to connect the sounds they hear to objects on the map, and thus their locations.

We recognized that the task of learning to associate sounds with objects has similarities to learning a language’s vocabulary – in both cases you are learning how to associate words and sounds with objects. There are a variety of potential solutions to this real-world problem, one of which is Duolingo, a successful [52, 72] online app developed with gameful design principles [1] to “... give everyone access to a personalized education in a scalable way” [52]. Duolingo’s design inspired the design of our training system.

Movement Sounds



Health Pickup Sounds



Armour Pickup Sounds



Weapon Sounds and Miscellaneous Sounds



Figure 5.4: The sets of audio cues.

The audio cues were grouped into sets, consisting of a collection of sounds and each sound's associated icon (or icons). The sets were selected with the intent of grouping cues with a common theme, if possible. Figure 5.4 lists the four audio cue sets that users trained with. In some cases, a single sound was associated with multiple variations of the same event. For example, the same sound that would be heard when picking up a shotgun is heard as when picking up a rocket launcher. When training those sounds, one of the possible icons would be randomly selected. The icons that users saw during the training were the same as those used for the modified HUD interface.

The training process was made up of rounds, where users would train or practice on one or more sets of audio cues. At the start of each round, because the audio cues being tested changed, the user saw an introductory page for that collection of cues (Figure 5.3), introducing the audio cues they would be hearing, and in some cases provided some instructions. For example, to introduce the movement sounds: "As a player moves through the environment, they generate sounds depending on what they are doing. You will now learn how to identify these sounds. Start by listening to each sound several times." On this page, the user can optionally play each of the sounds they would be training.

There are three types of questions each user must answer for each sound cue. The first type was intended to be very basic; the user is given a description of the sound (for example, "Jumping") and they must select the correct icon and sound combination (Figure 5.5). When the user makes a selection, the sound is played – this was to ensure that the user was exposed to both the correct icon and sound for the cue. The next two question types were more advanced, and were opposites



Figure 5.5: Basic question type.



(a) Selecting the correct sound based on the displayed icon. (b) Selecting the correct icon based on the displayed sound.

Figure 5.6: The two non-basic question types in the training system.

of each other. One involved studying an icon with its description, and choosing the correct sound (Figure 5.6 (a)) while the other involved listening to a sound and choosing the correct icon and description combination (Figure 5.6 (b)).

The system was designed to progressively increase in difficulty. This was accomplished in two ways. First, as mentioned previously, the process was broken up into rounds, with each round featuring one or more cue sets. The difficulty was increased by introducing new cue sets in addition to the one learned previously. Secondly, the questions the user answered were all the previously described basic type to start. There were two phases of questions – the first phase was the basic question type alone while the second phase involved the system randomly selecting one of the two more advanced question types. To move from the first phase to the second phase, the user must have had a positive score for each cue. The same was true when moving from the second phase to the next round, featuring a new collection of cue sets. When the user began a new collection of cues, the user had to go through the first question type again, but only for the new, untrained cues.

As mentioned previously, the user had to have a positive score to make progress. In the training system, the score was calculated for each cue and question combination. The score increased by 1

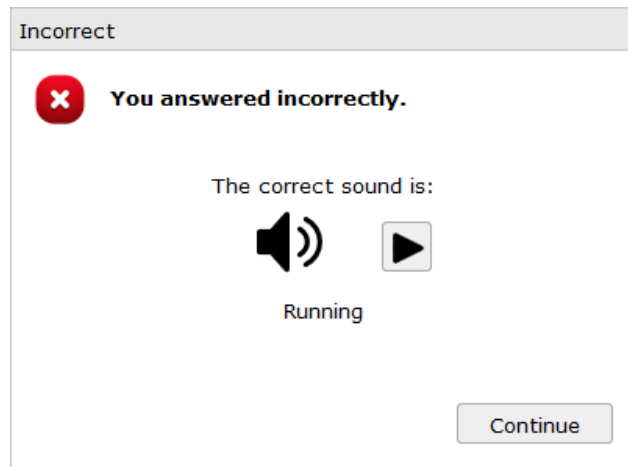


Figure 5.7: When the user chose an incorrect option, they were able to see or hear the correct option.

if the user answered correctly, and decreased by 1 if the user answered incorrectly – but only if the score was greater than 1. This was done so that repeated failures wouldn't hinder progress, because they only needed to get the last attempt correct to move on. As the user's overall score increased, the progress bar (see Figure 5.5) would move towards completion. If the user's score decreased, they would also see the lost progress. To help users learn from their mistakes, the correct answer was shown if they were to choose an icon, or a button to play the sound would be provided, as shown in Figure 5.5.

The cue that was selected as the answer each time was determined semi-randomly. First, three cues were chosen at random from the current cue collection, then from those three the one with the lowest score was selected as the answer. If there was a tie, then one was randomly selected. From this answer, the question was built. This was done to make the training slightly less repetitive, while still leaving some possibility that the same cue could come up multiple times. At the phase involving the two question types, once a user had a positive score for each cue for one particular type of question, that question would no longer come up.

CHAPTER 6

HELPING NOVICES LEVERAGE AUDIO CUES

(STUDY 2)

Having designed two systems for scaffolding a novice's use of audio cues – the interface approach of providing a visualization of the audio cues, and the training approach of teaching the novices the mapping between sounds they were hearing and the objects in the game – we were interested in evaluating how well novices were able to use these systems to help them locate opponents. Additionally, since the training takes place as a separate system, we were interested in determining of this efficacy of this training itself; would participants reliably be able to choose the correct cue each time? Additionally, how well would the cues be retained? Would they still be remembered after two weeks? We answered these questions by looking at the results of the final round of training for the participants who completed it as part of the training, and by re-inviting the participants who completed training to compete that final round of training again after two weeks.

6.1 Procedure

The procedure for this study was similar to Study 1 in that the same system was used, including the demographics questionnaire, scenarios, the questions asked about each scenario, and the post-scenario questionnaire. This was done because they were found to be effective tools for the purpose of evaluating this skill of utilizing awareness cues. The system was modified to integrate the two scaffolding systems. The modified HUD interface with icons was integrated by replacing the existing scenarios videos with videos that incorporated the interface and the training was integrated by having participants undergo it immediately before scenarios were presented. These two factors of HUD icons and training were crossed in a between-subjects design, creating four groups – no

scaffolding, the modified HUD interface, the training, and a combination of the modified HUD interface and the training. This allowed us to collect data for every possibility.

Participants first gave informed consent, after which they were automatically assigned to the group with the fewest participants. They first completed the demographics questionnaire, then, if they were assigned to a group with training, they underwent it before completing any scenarios. If they were assigned to a group with the modified HUD, they saw those videos during the process of responding to the scenarios. Once the scenarios were completed, they completed the post-questionnaire survey.

After two weeks, we invited participants who underwent training – either on its own or with the HUD icons – to complete a follow-up task that involved going through the final round of training once more. This allowed us to compare their performance after two weeks to their performance during the final round of training, when they presumably would have experienced their best performance at choosing audio cues in the training task.

6.2 Participants and Recruitment

An online study was again utilized, however, rather than recruiting from the variety of sources we did in Study 1, Amazon’s Mechanical Turk (MTurk) crowd-sourcing platform was used. MTurk is a tool that is used by businesses, individuals, and researchers to find paid workers willing to perform Human Intelligence Tasks (HITs). MTurk has been used for research purposes before and has been shown to be a reliable research tool [43].

Among other reasons, such as the ease of recruiting a large number of participants quickly, MTurk was chosen deliberately as it allowed us to increase the probability of recruiting novices who had never played *Quake Live* or potentially even a first-person shooter before. To avoid attracting participants with an interest in *Quake Live*, we ensured that the description of the HITs or “human intelligence tasks” posted made no mention of it. This was done because our scaffolding systems were intended to be used by novices with little to no expertise with the game.

We recruited participants with separate postings, or HITs. Participants who completed one HIT were assigned a “qualification,” which prevented them from completing the study twice. This was done because the training extended the duration of the study by about 15 minutes and so

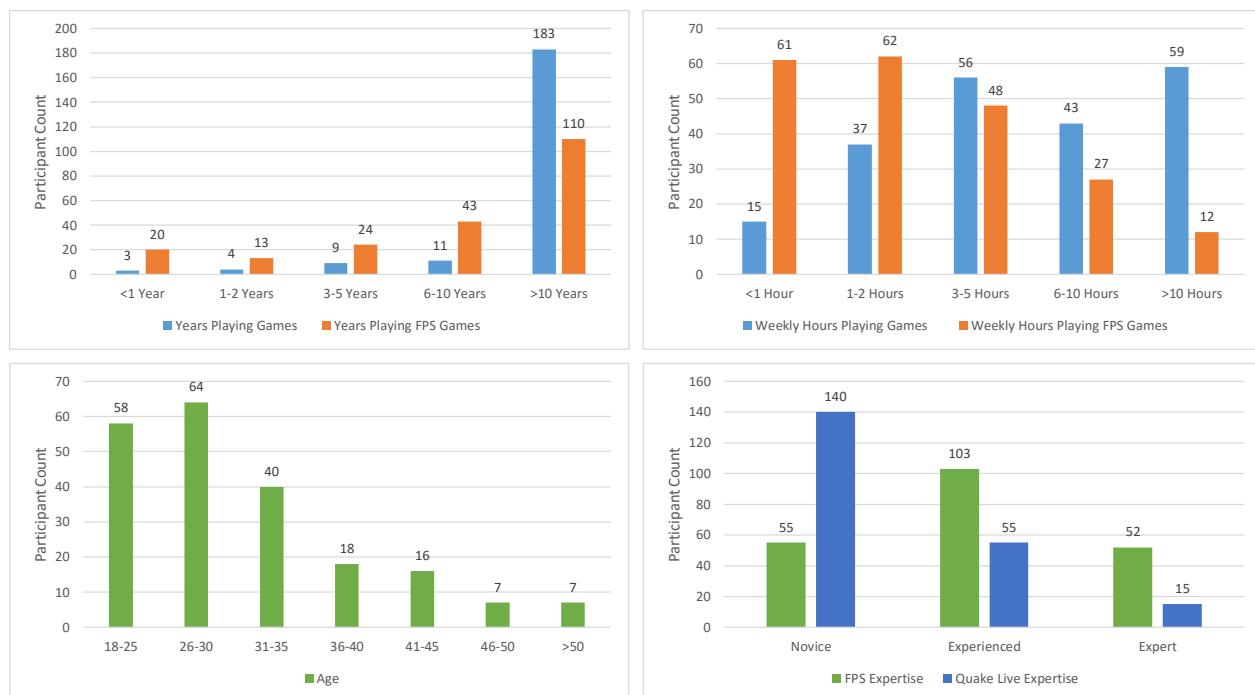


Figure 6.1: Demographics for Study 2.

these participants were paid more. Participants who completed the HIT that included the training scaffolding were told it would take 30-45 minutes and were paid \$5 for their time. Participants who completed the HIT without training were told it would take 15-30 minutes and were paid \$3 for their time.

A total of 232 participants completed the study. 22 participants were removed due to not watching the videos to completion or failing to make a guess on both of the straightforward introductory scenarios. This left 210 participants. Complete demographics information is shown in Figure 6.1. Over the four conditions, 51 participants completed the version with no scaffolding systems, 53 completed the version with the modified HUD interface, 54 completed the version with audio cue training, and 52 completed the version with the modified HUD interface and training combined.

Two weeks later, we launched an additional follow-up HIT to evaluate the retention of the trained cues. This was available to the 106 participants who underwent the training and were one of the 22 participants not previously removed from the analysis. 25 spots were available and were filled based on how quickly the workers responded to and accepted the HIT. This re-test consisted solely of what was the final round that participants would have completed during the training, and so contained all 13 audio cues. The HIT paid \$1 and was advertised as taking between 5 and 10

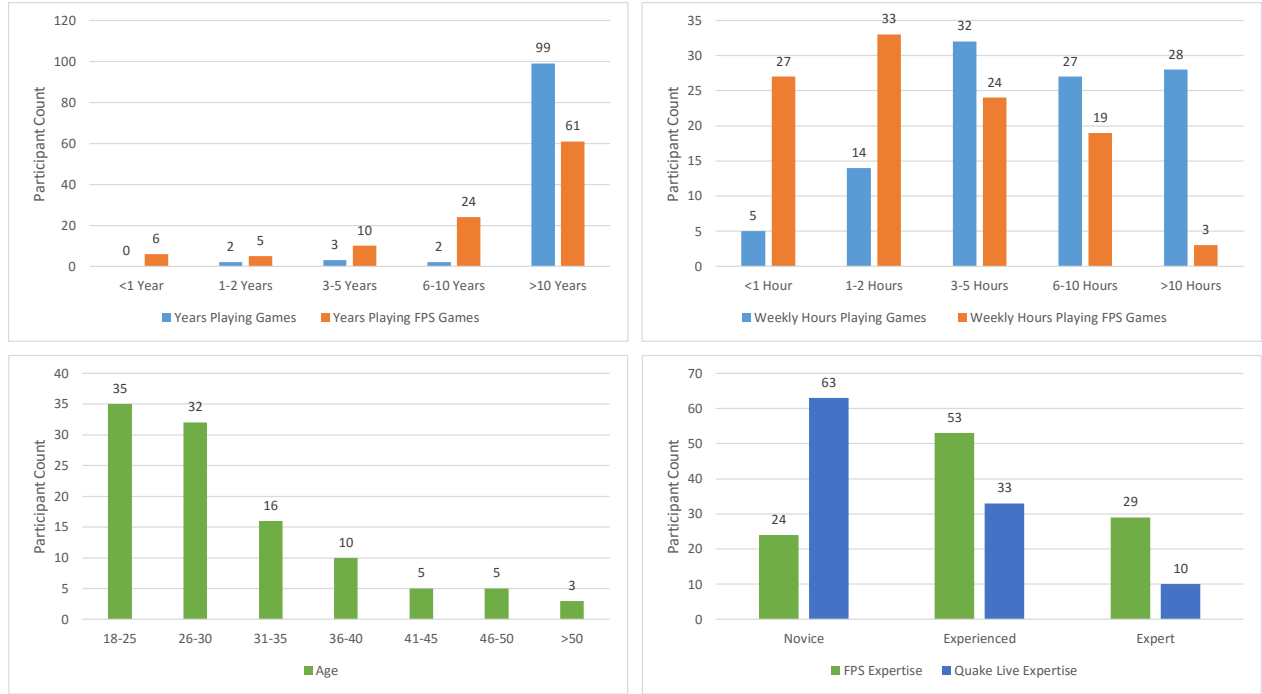


Figure 6.2: Demographics for those 106 participants who underwent training.

minutes.

Therefore, our results for the efficacy of the training system involve a comparison between the results of the 25 who answered the call for the follow-up and the 106 participants who underwent the training. Those 106 participants consisted of 33 female and 73 male participants, the majority of which were aged between 18 and 25 years. Only 10 (9.4%) of these participants rated themselves as *Quake Live* or *Quake 3* experts. Of the 25 participants who completed the follow-up, 7 were female and 18 were male, the majority were aged between 18 and 25 years old, and only 2 (8%) rated themselves as *Quake Live* or *Quake 3* experts. The complete demographics for the 106 who underwent training are in Figure 6.2, and the demographics for the 25 participants who completed the follow-up are in Figure 6.3.

6.3 Evaluating the Two Scaffolding Approaches

6.3.1 Scenario Groups

We first look at the performance of the participants in each of the scenario groups.

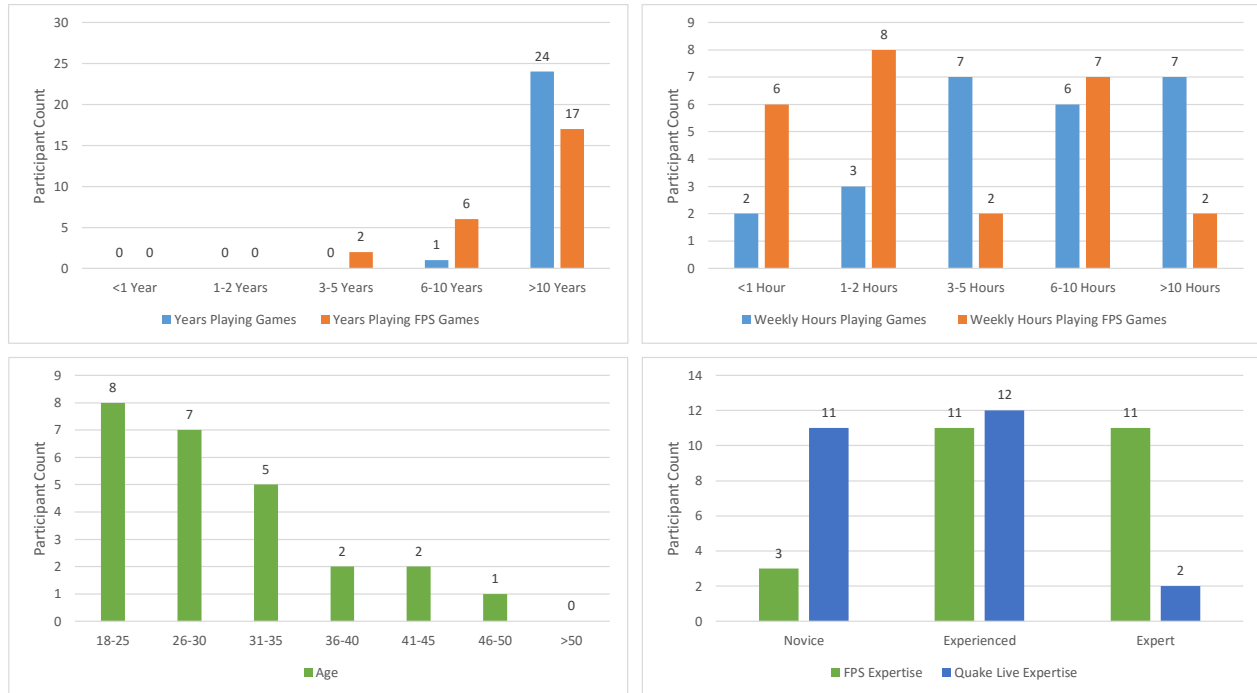


Figure 6.3: Demographics for the 25 participants who completed the follow-up.

Data Analyses

As in Study 1, we looked at the data as grouped by scenario type, but instead of comparing between expertise groups, we compared between the four interface/training groups. Also as in Study 1, we look at the same metrics of guess counts, confidence rating, and cue counts. We use these metrics to answer the following questions:

- Were participants more willing to make a guess?
- When they made a guess, were they more accurate?
- Were they more confident in their guesses?
- Were they able to identify more audio cues?

For the counts, including whether participants made more guesses and identified more cues, we were restricted to non-parametric tests, and thus used the Mann-Whitney test separately for both the modified HUD interface and training factors. Because of the limitation of non-parametric tests [19], we did not test for interaction effects between the two factors.

		No Scaffolding	HUD Icons	Training	Training + HUD Icons
Introductory Scenarios	Guesses	0.95 (.15)	0.95 (.15)	0.95 (.15)	0.94 (.16)
	Confidence	4.07 (.93)	4.14 (.93)	4.26 (.94)	4.28 (1.08)
	I Saw	1.02 (.34)	0.97 (.32)	0.98 (.27)	0.91 (.28)
	I Heard	0.36 (.50)	0.55 (.61)	0.72 (.68)	0.84 (.68)
Visually-Dependant Scenarios	Guesses	0.92 (.25)	0.97 (.12)	0.94 (.21)	0.99 (.07)
	Confidence	4.02 (1.09)	4.30 (.76)	4.19 (.86)	4.30 (.81)
	I Saw	1.12 (.41)	1.12 (.47)	1.10 (.45)	1.06 (.47)
	I Heard	0.40 (.66)	0.52 (.69)	0.43 (.60)	0.50 (.67)
Auditory-Dependant Scenarios	Guesses	0.53 (.37)	0.58 (.31)	0.62 (.34)	0.67 (.32)
	Confidence	2.05 (.97)	2.35 (1.01)	2.44 (.95)	2.80 (1.08)
	I Saw	0.05 (.12)	0.08 (.19)	0.03 (.10)	0.04 (.11)
	I Heard	0.86 (.71)	0.93 (.68)	1.20 (.67)	1.43 (.68)
	Note Correct	0.01 (.06)	0.09 (.24)	0.11 (.18)	0.22 (.31)

Table 6.1: Descriptive statistic results for Study 2's grouped scenarios.

		HUD Icons	Training
Introductory Scenarios	Guesses	$U=5460$ $p=.819$	$U=5470$ $p=.854$
	Confidence	$F_{1,206}=0.1$ $p=.731$	$F_{1,206}=1.5$ $p=.223$
	I Heard	$U=6261$ $p=.076$	$U=7098$ $p<.001$
Visually-Dependant Scenarios	Guesses	$U=5908$ $p=.138$	$U=5676$ $p=.374$
	Confidence	$F_{1,206}=2.6$ $p=.108$	$F_{1,206}=0.4$ $p=.509$
	I Heard	$U=5847$ $p=.401$	$U=2656$ $p=.717$
Auditory-Dependant Scenarios	Guesses	$U=5908$ $p=.349$	$U=6327$ $p=.054$
	Confidence	$F_{1,206}=5.5$ $p=.020$	$F_{1,206}=9.1$ $p=.003$
	I Heard	$U=5970$ $p=.294$	$U=7283$ $p<.001$
	Note Correct	$U=6244$ $p=.024$	$U=6839$ $p<.001$

Table 6.2: Results of statistical tests for Study 2's grouped scenarios.

For the confidence ratings, we performed a univariate ANOVA with two between-subject factors for each scenario type separately, using pairwise comparisons (least significant difference) to examine between-group differences.

Accuracy of the location guesses was evaluated as in Study 1, using heatmaps based on kernel-density estimation [41]. For the auditory-dependant scenarios we also examined the written responses for indicators of accuracy. These were specific words or phrases that the experts tended to mention in their responses in Study 1, such as the mention of a nearby landmark or the item for which the audio cue was heard.

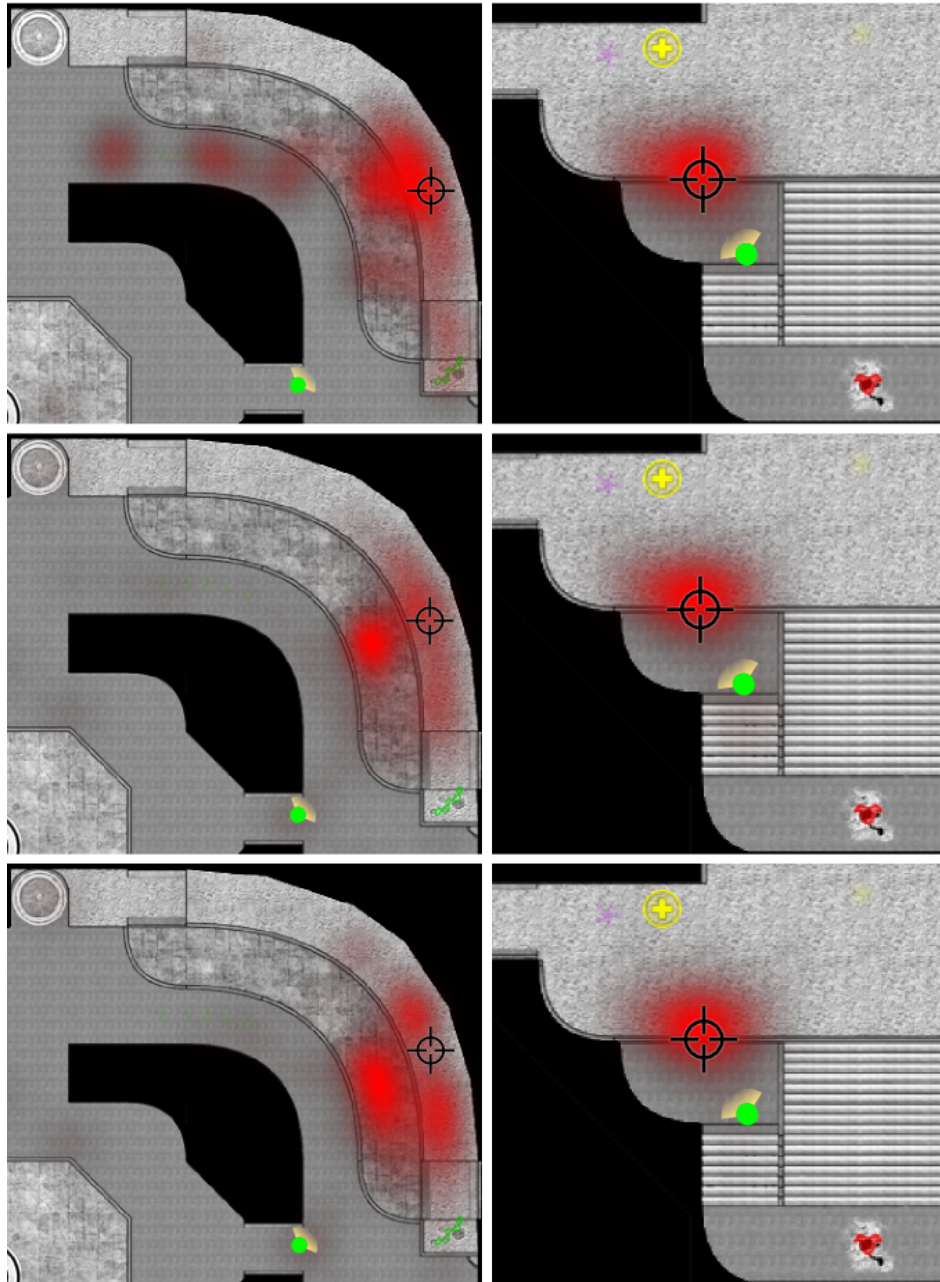
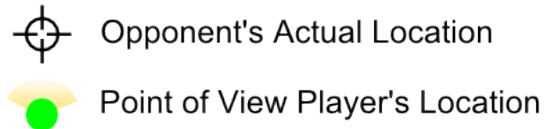


Figure 6.4: Heatmap of location responses for the introductory scenarios. The first column is scenario 1, the second is scenario 2. We compare between the different factors of HUD icons and training to compare the three groups represented by the columns. The first row contains responses of participants who received no scaffolding, the second contains responses from participants who had access to HUD icons and the third contains responses from participants who underwent training. The reticle indicates the opponent's location and the green circle indicates the point-of-view (POV) player's location.

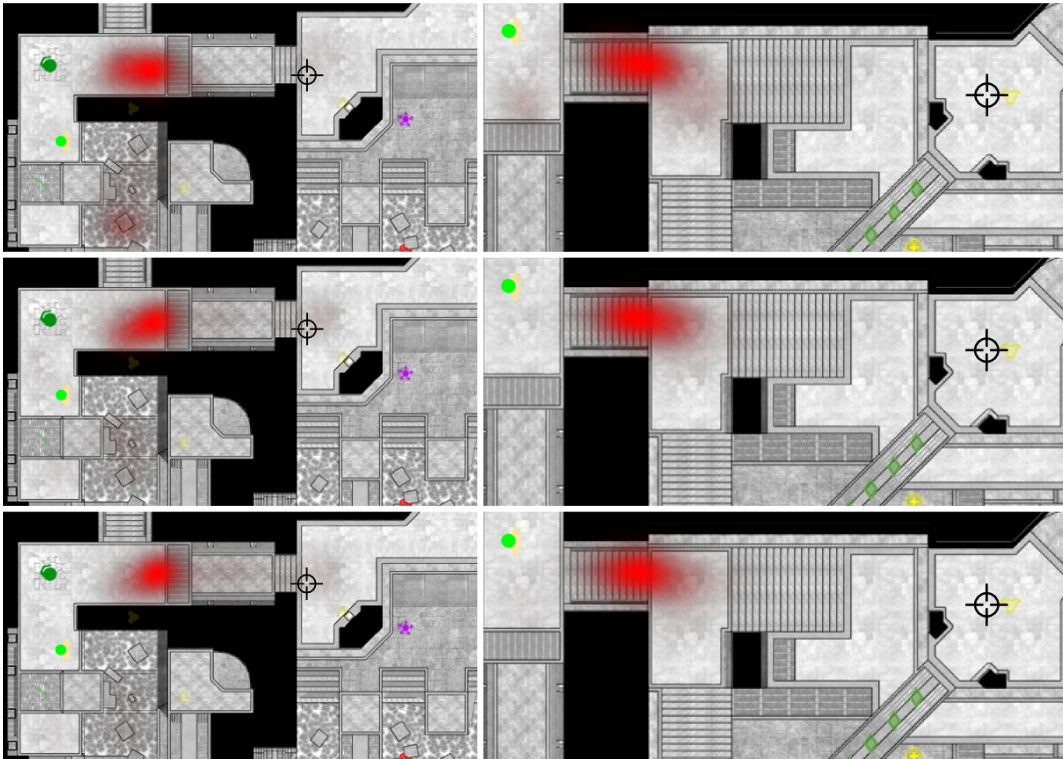
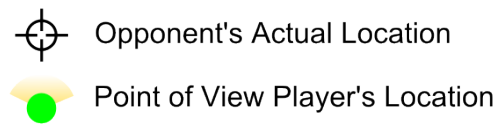


Figure 6.5: Heatmap of location responses for the visually-dependant scenarios. The left column is scenario 4, the right is scenario 6. The first row contains responses of participants who received no scaffolding, the second contains responses from participants who had access to HUD icons and the third contains responses from participants who underwent training. The reticle indicates the opponent's location and the POV player's location is in green.

Introductory and Visually-Dependant Scenario Results

We trained players to recognize audio cues, thus we expected that our systems would not improve accuracy or confidence in the introductory or visual scenarios. There were no main effects of training or HUD icons on either the number of location guesses participants made or the confidence in their guess (see Table 6.2). There were no interaction effects between training and HUD icons for the confidence for the introductory scenarios ($F_{1,206} < 0.1$, $p = .843$) or visually-dependent scenarios ($F_{1,206} = 0.5$, $p = .490$).

For the introductory scenarios, there was a significant main effect of training, (but not HUD icons), on the number of audio cues listed, in which training increased the number of cues listed; there were no significant main effects for the visually-dependent scenarios (see Table 6.2).

Auditory-Dependant Scenario Results

We trained players to recognize audio cues, thus we expected that our systems would result in improvements in the auditory-dependent scenarios.

Were participants more willing to make a guess?

There was a marginally significant main effect of training and a non-significant effect of HUD icons (see Table 6.2) on the number of guesses participants made, indicating that neither factor significantly increased the number of location guesses, although training trended in that direction.

When participants did guess, were they more accurate?

For scenarios 3 and 7, as seen in the heatmap (Figure 6.6), both scaffolding approaches helped participants make better guesses, with training appearing to help more than HUD icons in scenario 3. Those who received no scaffolding performed poorly while those who did were more likely to identify the opponent's correct location based on the item pickup audio cues they heard.

For scenario 5, neither scaffolding approach appeared to make a difference in accuracy. This may be due to the ambiguity of the teleporter's exit location, as teleporter exists were not labelled on the map as the item pickups were. Several responses by participants indicate that this was the case, e.g., "the other player went through the teleporter to it's (sic) destination, but I am unsure of

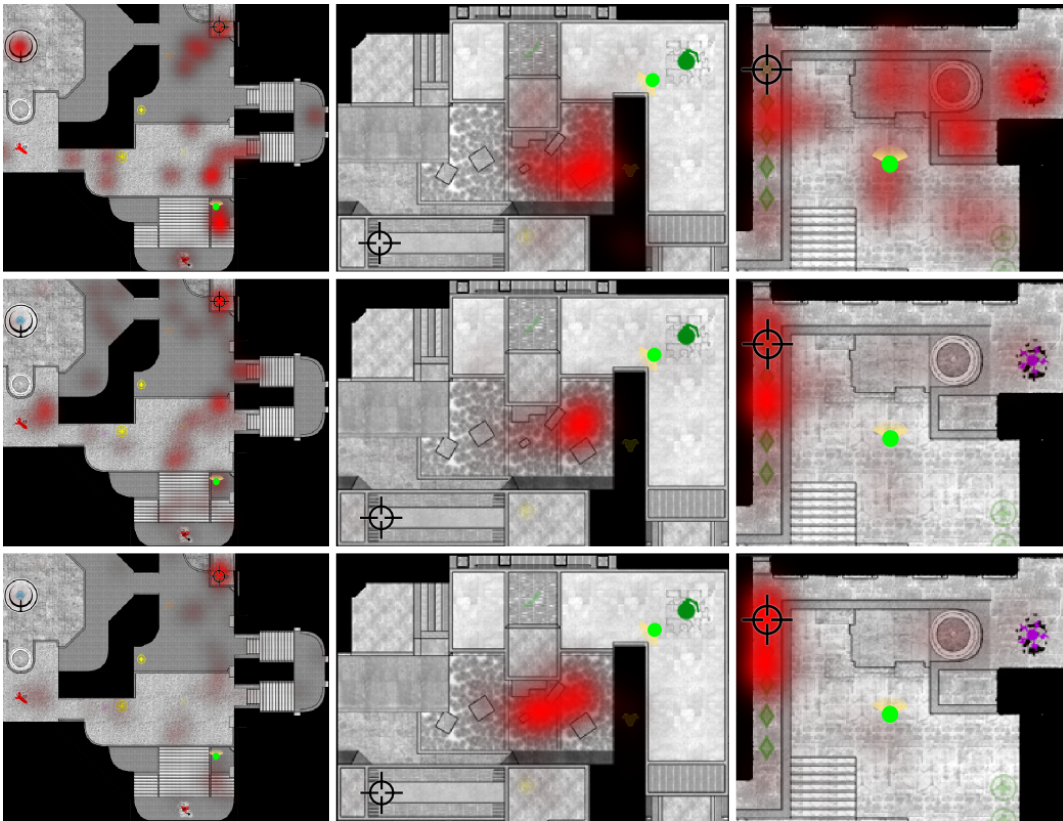
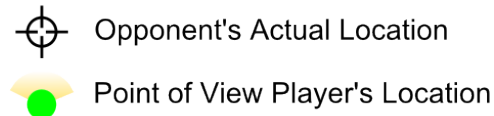


Figure 6.6: Heatmap of location responses for the auditory-dependant scenarios. From left to right, scenario 3, scenario 5, and scenario 7. The first row contains responses of participants who received no scaffolding, the second contains responses from participants who had access to HUD icons and the third contains responses from participants who underwent training. The reticle indicates the opponent's location and the POV player's location is in green.

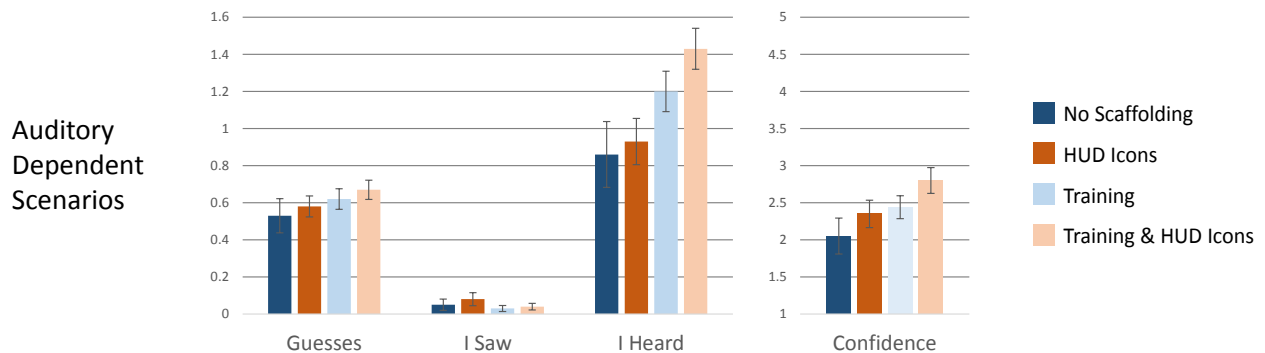


Figure 6.7: Charts of the descriptive statistic results for the auditory-dependant scenarios, compared between type of scaffolding. Error bars are standard error.

the destination on the map, or “I know they exited a teleporter, but those are not really labelled on the map.

There were significant main effects of training and HUD icons (see Table 6.2) on whether or not participants correctly identified the opponent’s location in terms of a landmark or its audio cue in their written responses, in which both approaches increased the number of such responses.

Were participants more confident in their guesses?

There were significant main effects of training and HUD icons (see Table 6.2) on the confidence rating, in which both approaches significantly improved confidence ratings. There were no significant interaction effects between training and HUD icons ($F_{1,206} < 0.1$, $p = .855$).

Were participants able to identify more audio cues?

There was a significant main effect of training but not HUD icons (see Table 6.2) on the number of audio cues listed, in which those who underwent training listed more audio cues. There were no significant interaction effects between training and HUD icons ($F_{1,206} = .631$, $p = .428$).

6.3.2 Questionnaire

We made use of the same questionnaire as was used for Study 1, asking participants about how important they perceived different aspects of the task to be as well as how difficult they felt different aspects of the task were.

Data Analyses

For the questions asking participants to rate the importance of different aspects of the task, we used a 5-point scale, where 5 was more important. For the remaining questions asking about difficulty, we also used a 5-point scale, where 5 was more difficult.

For all of the questions, we performed a univariate ANOVA with two between-subject factors for each question separately, using pairwise comparisons (least significant difference) to examine between-group differences.

Question	HUD Icons	Training	Interaction
1. How important is it to know where your enemies are?	$F_{1,206}=.103$ $p=.749$	$F_{1,206}=2.07$ $p=.152$	$F_{1,206}=.041$ $p=.840$
2. How important is knowledge of a specific game when locating other players?	$F_{1,206}=3.25$ $p=.730$	$F_{1,206}=.357$ $p=.551$	$F_{1,206}=.003$ $p=.959$
3. How important is knowledge of the specific map or level when locating other players?	$F_{1,206}=1.50$ $p=.221$	$F_{1,206}=.001$ $p=.981$	$F_{1,206}=.066$ $p=.798$
4. How difficult was it to get an idea of where the other player was?	$F_{1,206}=.005$ $p=.943$	$F_{1,206}=.007$ $p=.932$	$F_{1,206}=.378$ $p=.539$
5. How difficult was it to describe with words where the other player was?	$F_{1,206}=.181$ $p=.671$	$F_{1,206}=1.40$ $p=.238$	$F_{1,206}=.018$ $p=.894$
6. How difficult was it to point out where the other player was on a map?	$F_{1,206}=.034$ $p=.854$	$F_{1,206}=2.46$ $p=.118$	$F_{1,206}=1.04$ $p=.309$
7. How difficult was it to name the cues that helped you know where the other player was?	$F_{1,206}=3.23$ $p=.074$	$F_{1,206}=9.36$ $p=.003$	$F_{1,206}=.959$ $p=.329$
8. How difficult was it to connect sounds to specific objects in the game?	$F_{1,206}=8.92$ $p=.003$	$F_{1,206}=21.9$ $p<.001$	$F_{1,206}=.924$ $p=.338$
9. How difficult was it to connect sounds to locations on the map?	$F_{1,206}=2.40$ $p=.123$	$F_{1,206}=4.96$ $p=.027$	$F_{1,206}=.112$ $p=.739$
10. How difficult was it to understand what was happening in the videos?	$F_{1,206}=.006$ $p=.938$	$F_{1,206}=.042$ $p=.837$	$F_{1,206}=6.05$ $p=.015$

Table 6.3: Results of Study 2's questionnaire.

Results

For the three questions on importance as well as questions 4, 5, 6, and 10 on difficulty, there were no main effects of HUD icons and training on whether they found the aspects of the task of locating opponents to be more or less important or difficult (See Figure 6.3).

For question 7, “how difficult was it to name the cues that helped you know where the other player was?”, we found significant main effects of training but not HUD icons (See Figure 6.3).

For question 8, “how difficult was it to connect sounds to specific objects in the game?”, we found significant main effects of both training and HUD icons on whether or not participants found this task difficult, in which both HUD icons and training resulted in participants finding the task easier. There were no significant interaction effects between training and HUD icons.

For question 9, “how difficult was it to connect sounds to locations on the map?”, we found significant main effects of training but not HUD icons (See Figure 6.3).

6.3.3 Summary

Because the system we developed for use during Study 1 worked well, we utilized it again to evaluate our two scaffolding systems and check whether participants improved at locating opponents. We recruited participants through Amazon’s Mechanical Turk, which gave us far fewer experts than our recruitment method for Study 1, as was our intention. Participants were assigned to one of four groups, which were created by crossing the two factors of HUD icons and training in a between-subjects design.

Our scaffolding systems focused on introducing auditory cues to new players, thus we did not expect to find any difference between the groups for the introductory and visually-dependent scenarios. Our results confirmed our expectations, with one exception – participants who underwent training listed more audio cues in the introductory scenarios. The remainder of the differences were found in the auditory-dependent scenario results. There, we saw that although the scaffolding systems didn’t increase the number of guesses, both resulted in increased confidence and training resulted in more cues being recognized and listed. We also saw increased accuracy in terms of the ways in which participants wrote out their guesses and in the heatmaps for two of the three scenarios. The general trend was that although the HUD icons did help, training helped more.

This trend continued into the questionnaire results. Participants who were given the HUD icons as scaffolding felt that it was easier to connect sounds to specific objects in the game, but nothing else. On the other hand, those who underwent training not only found it easier to connect sounds to objects, but then connect those sounds to specific locations on the map. They also found it easier to list those cues

6.4 The Efficacy of the Training System

6.4.1 Data Analyses

We present the descriptive statistics (see Table 6.4) of the final round of the training, which included all audio cues, as well as the final round the re-test, which also included all the audio cues. The means and standard deviations are presented for both two advanced question types (as described in Chapter 5) of selecting the correct icon based on the sound and select the correct sound based on

Audio Cue	End of Training (<i>n</i> =106)			Re-test (<i>n</i> =25)		
	IFS	SFI	Both	IFS	SFI	Both
Jump Pad	99 (6)	97 (10)	98 (7)	100 (0)	97 (12)	98 (6)
Jumping	98 (11)	98 (8)	97 (9)	95 (13)	97 (12)	95 (13)
Running	98 (10)	100 (3)	98 (7)	100 (0)	100 (0)	100 (0)
Running in Water	100 (0)	100 (0)	100 (0)	98 (10)	100 (0)	99 (7)
Teleport	96 (13)	99 (6)	97 (8)	93 (16)	97 (9)	94 (12)
Pickup Health (+5)	93 (15)	95 (15)	93 (13)	82 (25)	97 (13)	87 (19)
Pickup Health (+25/+50)	91 (18)	96 (13)	92 (14)	82 (24)	93 (17)	85 (17)
Pickup Mega Health (+100)	94 (14)	98 (8)	96 (10)	87 (21)	97 (12)	91 (13)
Pickup Armor (+5)	98 (8)	97 (11)	97 (9)	100 (0)	89 (4)	92 (16)
Pickup Armor (+25/+50)	98 (9)	97 (11)	97 (8)	100 (0)	100 (0)	100 (0)
Pickup Weapon	99 (5)	98 (7)	98 (5)	93 (12)	98 (5)	95 (8)
Change Weapon	98 (10)	95 (14)	95 (11)	99 (7)	89 (18)	92 (12)
Item Respawned	99 (6)	98 (8)	98 (7)	94 (15)	96 (14)	94 (13)
Combined	96 (5)	96 (5)	96 (4)	94 (6)	91 (8)	92 (7)

Table 6.4: Descriptive statistics of participant performance (as a percent) in the training system. Standard deviation is in brackets. IFS = Identifying the correct icon/description based on the sound. SFI = Identifying the correct sound based on the icon/description.

the icon. Additionally, the statistics for the combination of both question types is presented.

Performance is represented as a ratio of the number of correct responses over all the responses for each audio cue, in order to handle the varying number of trials as a result of adding wrong responses back into the “queue” (see Chapter 5 for more detail).

6.4.2 Results

We found our training system to be effective for teaching users the audio cues (see Table 6.4), with the final overall accuracy being 96%. The worst performing cue resulting in 91% accuracy and the best performing cue resulting in 100% accuracy.

We found that participants generally were able to retain the audio cue information two weeks after training (see Table 6.4). We found that participants retained their understanding of the previously trained cues, although there was a slight drop in the correct identification of the pickup cues that were easily confused with each other. The average accuracy fell from 95% to 92% for pickup cues and 97% to 96% for the other cues.

6.4.3 Summary

We were interested in evaluating the effectiveness of the training system. This was done as part of a larger study by having 106 participants use the system to learn the audio cues for the game *Quake Live*. The long-term effectiveness was also evaluated by having 25 participants complete a re-test that could be compared to the final round of training. We found that the training system was effective for teaching the users the audio cues, and that performance remained relatively stable, even after two weeks without training or practice.

CHAPTER 7

DISCUSSION

In this chapter, we discuss various topics relating to the work presented in this thesis. We start by looking at awareness cues themselves, such as how they tie into the actions players take while playing first-person shooters. Following this, we discuss various aspects of scaffolding systems, including the differences between our two systems, what instructional scaffolding actually means, why the awareness cues were retained so well over time, how scaffolding systems fit into the two main skill development models that we introduced in Chapter 2 – Fitts and Posner’s three stages of development, and Killi’s model of experiential learning in games – and how scaffolding is currently utilized in commercial games. Last, we examine scaffolding’s potential impact on play experience and discuss potential directions future work as well as limitations of this work.

7.1 Types of Awareness Cues

Visual and auditory awareness cues in first-person shooters are intrinsically linked together – every auditory cue has a visible player action associated with it, whether that’s firing a weapon, walking, or picking up ammunition. In this way, every awareness cue can be considered one of Gaver’s [26] “auditory icons” – they are based on a player’s real-world intuition and change both in volume and spatially (in stereo, left-right audio balance) depending on the player’s orientation and position relative to the object. Stockburger [66] would describe these awareness cues as being able to be visualized (both heard and seen) or acousmatized (heard but not seen) because the player has the option of seeking out the source of the sound.

This is where the power of audio cues comes from. They allow an expert to understand an opponent’s actions and relay important tactical information about an opponent that the expert can utilize, without needing that opponent to be visible, meaning that they can stay a safe distance away.

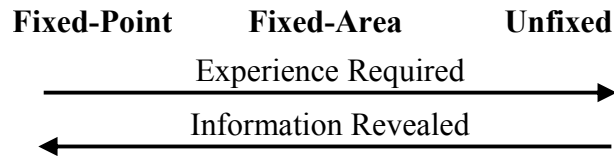


Figure 7.1: The different categories of audio cues and the relationships between requisite knowledge and the degree to which the other player’s location is revealed.

While this most notably includes an opponent’s current location, it also includes the knowledge that an opponent’s health, armour, or ammunition has increased, or that they have gained access to new weaponry.

This ties into many of the strategic aspects of arena FPS games such as *Quake Live* that are made apparent by various online guides [21, 50] as well as the work by Conroy et al. [13] on threat assessment. For example, experts learn the importance of paying attention to the status of important strategic items that will allow them to have an advantage over their opponents. They want to be the one to pick up the item, and want to prevent their opponent from taking it. To accomplish this, the expert will time the items. This involves noting the time the item was picked up and, because the items respawn in a fixed amount of time, they simply need to be in the vicinity of the item when it becomes available next. Then they can take the item for themselves if it is safe to do so, or attempt to damage their opponent who takes the item in order to minimize the advantage that the item gives them. It all comes down to trying to gain an advantage over one’s opponent or being aware of the current threat that they pose. When a player is sure that they are better equipped than their opponent, they know they can attack with a greater chance of success.

In choosing scenarios and designing the system to evaluate a player’s ability to utilize awareness cues, it became apparent that there are some types of auditory cues that reveal more than others. For example, footsteps reveal an opponent’s approximate location or specific direction, while a specific item pickup sound is able to reveal an opponent’s exact location. We have identified that auditory awareness cues can fit into one of three categories, based on how much information is revealed, as shown in Figure 7.1.

The first category, fixed-point, refers to those audio cues that originate from a static point within the game environment. These include such cues as item pickup sounds, teleporter sounds, or more organic sounds such as doors opening or elevators moving. The next category, fixed-area, includes those sounds which can be connected back to a fixed area within the environment. This category

is made up of sound cues created by a player interacting in or with the environment itself, such as splashing water, rustling bushes, or the transition from one ground type to another (e.g., stepping from dirt to concrete as the player enters a building). The final category, unfixed, is for sound cues that cannot be definitively linked to a specific location, and includes sound cues such as gunfire, footsteps, and jumping.

However, there's an interesting relationship whereby the cues that reveal more about an opponent's location actually require less player experience or knowledge to utilize (see Figure 7.1). All types of cues require a basic understanding of the current map's layout, but fixed-point cues require only that a player knows where specific items are on the map. That knowledge is combined with an understanding of what sound a player is hearing and be able to connect that to a specific item which is then connected to a specific location on the map. A player doesn't need to utilize the spatial nature of the game's sound effects in order to perform this type of opponent locating. Fixed-area cues require further map knowledge (e.g., locations of doors or pools of water), and in some cases require a player to listen for changes in sound cues (e.g., moving between ground types). When understood, fixed-area cues are able to reveal the area an opponent is in, rather than the exact point on the map. Unfixed cues reveal even less about a player. They require a player to fully utilize the spatial nature of the game's audio (e.g., changes in volume and audio balance) as well as have familiarity with the levels passageways and allow a player to narrow down the number of routes the opponent may be taking or whether they are heading towards or away from them.

7.2 The Differences Between Our Two Scaffolding Systems

In Study 2, when we analyzed the differences between our two scaffolding systems, we found that while both increased accuracy and confidence, training seemed to perform better, leading to more guesses being made and more auditory cues being recognized and listed. There are many possible reasons for why this is.

Our intent was to compare between helping a player access the auditory cues visually by seeing it appear on a HUD versus accessing the auditory cues as intended by listening and understanding the sound. However, in order to allow the player to effectively understand the auditory cues, they underwent training, which gave them time to familiarize themselves with the mapping between

sounds and objects. On the other hand, players given only the HUD icons did not have additional time to familiarize themselves with the objects at all. A more direct comparison to the HUD icons would have been to provide an auditory legend of the various sounds of the game, similar to the visual legend of the HUD icons that was provided (Figure 5.2). This “legend” could provide players with buttons beside each description that played back the sound that was associated with the action described.

Another factor is that even though all of the information was presented to users of the HUD icon scaffolding system, the users may not have been motivated enough to access it. The icons may have sufficiently highlighted the importance of the auditory awareness cues, yet the user was still required to understand what those icons meant. This would have been done by studying the provided legend, which described the meanings of the icons. This legend was shown to the user before any scenarios were responded to, and was accessible throughout the scenarios by clicking on a link near the video playback window. Therefore, even if the participant saw the HUD icons and recognized that they were important, they still may not know what they meant. Combine this with the fact that not all Mechanical Turk workers would be intrinsically motivated to determine the correct answer by accessing the legend and comparing it with what they observe, it is reasonable that the HUD icons would not do as well as the training, where the correct meanings are effectively drilled and practised until the participant can correctly identify the sounds they are hearing and their meaning.

One might argue that there is already too much visual information to keep track of, and so the HUD icons were overlooked. Certainly there would be cases of this in actual gameplay, but because of our hand-picked scenarios but this seems like an unlikely explanation. The auditory-dependent scenarios we chose all involve little to no visual information for the participant to utilize, so their attention is more likely to be drawn to our HUD icons. Additionally, for the scenarios chosen, the point of view player created few auditory cues themselves that would have confused the participant.

We observed that those who underwent training performed better than those who were only given the HUD icons, but the combination did the best (Figure 6.7). It appears as though the addition of HUD icons on top of the training may have helped to reinforce what participants had learned.

The training scaffolding worked quite well, however, it has one significant limitation when

compared to the HUD icon scaffolding – it must be intentionally sought out by the player. On the other hand, the HUD icon scaffolding system can be seamlessly integrated into the player’s current game experience and utilized or ignored at will. The need for the training to be completed separately also has advantages, however. It means that you have the user’s complete attention and can create a specific guided experience for them to learn in.

7.3 Are Our Systems Actually Instructional Scaffolding?

In defining instructional scaffolding, the term “zone of proximal development” [77, 44] comes up. This refers to what a learner can’t yet achieve, but could with some additional guidance. The idea of scaffolding then, is to provide a learner with a temporary “boost” so that they can complete a task just beyond their current skill level. Once the student masters that task, the scaffolding is no longer necessary and can therefore be removed.

Therefore, a proper instructional scaffolding system for a game needs to consider the player’s current skill level in order to provide an adequate level of guidance, and if it serves its purpose well, then the player will reach a point where they no longer need it.

Based on this definition, neither of our two scaffolding systems are truly scaffolding systems. The primary issue is that neither consider the player’s current skill level. This is a consequence of pioneering the idea of scaffolding this particular skill – before our contribution, there was no way of measuring one’s expertise level with this skill. In Study 2 we worked around this by aiming to recruit participants that were relative novices at first-person shooters. Then we could be assured that we were targeting players who needed guidance with the skill of location opponents through the use of auditory awareness cues.

In terms of providing a boost to complete specific tasks, the HUD icons approach may fit better than the training. The reason is because the training system briefly takes players away from the specific problem and so it may not be obvious to the player that they’re mastering a specific skill that they were previously struggling with. The HUD icons are used within the context of the specific problem, so it may be more evident to the player that they are receiving guidance on how to solve a particular problem.

One thing that our systems do correctly to fit this definition of scaffolding is that the players

will indeed reach a point where the scaffolding is no longer necessary. This is directly true for our training system, which wasn't present when the player's performance was being tested; however, it is easy to see that players will eventually reach a point where the HUD icons would provide no additional usefulness – after all, that's how current experts are currently playing the game and the HUD icons did provide a boost to the novice's performance.

If we were to make a true scaffolding system for this skill, we believe it could be created by re-using our existing systems. The system would start by having participants watch and respond to scenarios as we did before. Based on this, training for specific cues could be completed. Following the training, participants would then respond to a new set of similar scenarios to verify that the scaffolding worked. If they did not respond correctly, they could undergo even more training until they did.

7.4 Retention of the Cues

For Study 2, we re-tested participants who underwent training to compare their performance immediately after completing the training system to their performance after a two-week break. We found that their overall performance dropped from 96% to 92% accuracy overall. Breaking this down a bit, we found that for pickup cues it fell from 95% to 92% and for the remaining cues it fell from 97% to 96%. It seems that the performance only significantly dropped if there was ambiguity as to the meaning of the cue. For example, participants easily differentiated between the “running” (98% originally to 100% during retest) and “running in water” (100% to 99%) cues, but there was confusion surrounding the similar sounding pickup cues. For example, “pickup health (+5)” (93% to 87%) and “pickup health (+25/50)” (92% to 85%). In summary, the straightforward cues were easy for them to remember and so performance remained the same, but for the more ambiguous cues, the performance only decreased slightly.

The argument could be made that if participants are confused between, for example, “pickup health (+5)” and “pickup health (+25/50)” that the impact on their experience will be minimal because they will still understand that the other player has picked up some amount of health. It's possible that this is the intent of the game designers – make the cues with similar meaning sound similar so that the general “meaning” (e.g., health pickup vs. armour pickup) of the cues can be

understood more quickly, but still different enough that the experts can discern exactly what item was picked up (e.g., the +5 health pickup vs. the +25 health pickup).

7.5 Facilitating Skill Development with Scaffolding

The scaffolding systems we provided assisted in the learning process and led to rapid improvements. The systems primarily helped the participant in the early stages of the learning process – practice is still required to master the skill. We look at how each system assists with learning in the context of Kiili’s experiential learning model and Fitts and Posner’s three stages of skill development.

The training system primarily helps players during the ideation phase in Kiili’s model; an understanding of the sounds they are hearing allows them to incorporate that knowledge into potential solutions to the problem of locating opponents. In the same way, it would assist with Fitts and Posner’s cognitive phase and help players settle on a strategy for locating enemies. During the associative phase, the player – having already learned how to differentiate sounds and understand how they can be applied in the game – can focus on improving.

The modified HUD interface system also assists with Fitts and Posner’s ideation and cognitive phases. However, it does so by visually highlighting the information; the user may not know what it means, just that it may be relevant to the problem. Therefore, it is doubtful whether it would be beneficial during the associative and autonomous phases, because the modified HUD could result in a dependence on the interface, rather than the correct approach of listening to the sounds.

For both systems, whether or not the player is able to reach the associative phase will depend on whether or not they are able to successfully practice the skill of identifying and using audio cues. A training system similar to our scenario-based test system could potentially provide an environment for practicing and ultimately mastering the skill of awareness cue recognition.

7.6 Scaffolding and Commercial Games

Singleplayer games do an excellent job of introducing new concepts to novices, allowing them to master skills and have fun doing so [29, 40, 58]. Game designers know approximately what skill

level a player will be at because they are in control of the player's experience – they are able to control the path that a player takes throughout the game. They design the challenges that a player will face and are responsible for ensuring that the player has the skills they need to make progress or overcome those challenges. Whether intentionally or unintentionally, they make effective scaffolding systems that introduce new skills to novices and provide guidance during those instances when players may feel stuck or lost.

Multiplayer games provide a player with a far less guided experience that does not have the same opportunities for scaffolding. On top of the reality that no two players will experience the same introduction to the game, there is also the added complication that the game's difficulty level is determined by the other players in the game. A new player has only a few options if they want to pick up a new multiplayer game:

- Fail repeatedly until the skills are learned
- Ask a friend for guidance
- Seek out assistance from an online source
- Refer to the in-game tutorials (if any)

Neither of these options are necessarily appealing. Failing repeatedly tends to be a very frustrating experience and may lead to the player quitting prematurely, before they've acquired the necessary skills. Experiencing failure will likely be the new player's first experience before they seek out guidance, and when they do, their current options aren't so great. Asking a friend for help is the closest that a player can come to utilizing scaffolding – the learner will interact with their friend and as long as their friend understands the skills well enough, they could guide the learner to help them achieve or master a new skill. Both seeking out assistance from an online source and utilizing in-game tutorials can work, but they both have the same problem – they do not consider the player's current skill level.

Developers have been making attempts recently to improve the experience for new users, for example by providing more comprehensive tutorials or creating systems specifically for the benefit of novice or weaker players. We can't cover every example, but we will cover a few relevant or notable ones.

Psyonix's *Rocket League*¹, which is a soccer game where the players control rocket-powered cars, features good example of tutorials that are useful to both new players and players with some amount of experience already. The game features a basic tutorial that introduces the concept of the game to novices, and additionally features 3 types of training modes for the various skills players can master: goalie – intercepting balls that are travelling towards your own goal, striker – striking the ball so it travels in the direction of the opponent's goal, and aerial – striking the ball while it's travelling in the air through the utilization of the car's rocket boosters. For each of these skill training modes, there are multiple difficulty levels that feature increasingly difficult scenarios that players may encounter. Additionally, the game features a free play mode that allows the player to experiment in a risk-free sandbox environment. Although these tutorials are useful, they still suffer from one main drawback – players must actively seek them out. An ideal scaffolding system would be able to identify skills a player is struggling with and adaptively provide guidance to the player.

A recent FPS, *Overwatch*², has also taken steps to ensure a positive first experience for novices. New players are encouraged to complete a brief tutorial that covers the basics of movement, firing your weapon, capturing objectives, and also introduces the idea of hero abilities by having you try out one of the 22 heroes. While this may sound sufficient, it ultimately fails to prepare the player for online multiplayer – the main mode of the game. When a player starts playing, they have no concept of what other objectives they may encounter, the abilities of each hero, what the various hero classes mean (tank, support, offence, defence), or the layouts of the map. Fortunately, matchmaking does help mitigate some of these issues, but users are still left with a period of repeated failures in order to learn these concepts. Probably the most disappointing part of this is that discovering and learning how to play a class – what arguably should be a very enjoyable feature of the game [40] – becomes an experience of repeated failures with the occasional breakthrough in understanding. In order to learn how to play a new hero effectively without this process involves going through the game's menus, studying how other players are playing, or researching online guides.

A less recent example, but relevant because we utilized the game in our studies, is an update [53] applied to *Quake Live*³ that had the intent of providing a better experience for novices and specifically focused on reducing the barriers of “effectiveness on spawn, movement, and item con-

¹Psyonix, 2015

²Blizzard Entertainment, 2016

³id Software, 2010

trol” [53]. To increase effectiveness on spawn, their solution was to allow all players to choose two starting weapons instead of starting with only the machine gun. To help with movement, in particular a technique known as “strafe jumping,” a skill that requires finesse and practice in order to move quickly, they introduced what was effectively a novice mode where players could simply hold the move forward and jump buttons to gain speed. Finally, to help introduce new players to the concept of item control, they introduced timers that show up in place of items that have been taken and are going to respawn. The timers show a “pie timer” that indicates how much more time needs to elapse before the item will respawn again. This “pie timer” also would reveal item locations to novices, because it would be visible even when the item was not, so they could more easily learn where to go for particular items.

7.7 Scaffolding’s Impact on Play Experience

The aim of scaffolding systems is to take the frustration out of the learning process, but what other impacts, if any, might it have on a player’s experience versus letting them learn experientially? From flow theory we know that the most immersive experiences are ones where the player’s skills are well-matched to the challenge level [15] – scaffolding systems are designed to bring new players up to speed quickly and allow them to compete fairly against other players. They do this by scaffolding the player to make use of skills that the better players already have learned – this should create more players who are at a similar skill level to one another, which would lead to a greater chance for all players to experience well-matched challenges. Self-determination theory tells us that feelings of competence – completing and overcoming challenges effectively – enhance one’s intrinsic motivation to complete a task [58]. Providing scaffolding simply accelerates this process.

The learning process itself can be enjoyable, so would scaffolding systems take this source of enjoyment away? We know that learning and mastering skills to overcome challenges is a major contributor to a game’s enjoyment [29, 40, 58]. There’s no concrete evidence to suggest that providing aid during this process will negatively impact the game’s enjoyment. In fact, if you consider games that scaffold this learning process particularly well, they are often well regarded among the gaming community. For example, consider *Portal*⁴ as a good example. *Portal* is a game

⁴Valve Corporation, 2007

about mastering a unique new skill, and the player’s learning is scaffolded throughout, yet despite of (or in fact, *because of*) this scaffolding, it was met with universal acclaim among critics and users alike⁵.

7.8 Limitations and Future Work

In this work, we evaluated an approach for scaffolding novice players in a particular skill, with the intent of minimizing skill discrepancies in multiplayer first-person shooters. To solve this problem, we used a unique approach of identifying what exactly makes an expert in an existing game, and then training novices to do the same. We tested participants online, having them watch and respond to video scenarios. The nature of this implementation led to a number of limitations, and our findings prompt us to consider ideas for future work.

Online testing gave us the luxury of gathering data from a wide range of participants, including experts who may have been difficult to find and contact locally. In order to accommodate this online testing, we could not utilize an interactive 3D FPS game, and so in its place we had participants view pre-recorded video scenarios and collected data by asking them to respond to questions. When asking them to try to locate their opponent, instead of having them navigate the 3D environment that they saw in the videos, they were asked to use a top-down 2D representation of that environment. This lack of a 3D environment to navigate could have led to confusion in interpreting the top-down 2D map, especially for novices not familiar with the game.

The video scenarios could be watched and re-watched. If the participant had been playing out the experience themselves, their experience would be completely different due to the increased involvement – novices may have found themselves feeling anxious [11] as they may have been overwhelmed by everything going on. In contrast, watching a video scenario isn’t as immersive, and when combined with no time constraint, meant that participants may have been less likely to respond in the same way as if they were playing. This likely led to more thoughtful responses, which may have resulted in scaffolding greater improvements than if the participant was actually playing. Future work must look into and verify that the improvements do indeed translate to increased in-game performance when the participant is playing the game. This is the logical immediate next

⁵See Metacritic: <http://www.metacritic.com/game/pc/portal>

step for this research.

One significant point of concern for us was the self-rating of FPS expertise level. This was done because we lacked any other way of quickly measuring or collecting expertise levels. We were concerned because each participant may have had a different idea of what it means to be an expert versus what it means to be a novice. For example, a novice may think anyone who plays the game at all is an expert because they would get annihilated by them, while an expert may underestimate their skill, thinking that the only professional e-sport players are experts. In practise, it ended up working for us – we were able to identify clear differences between the groups in Study 1, and for Study 2 its impact was minimized due to the focus on recruiting novices. A potential direction for future work is to devise an objective measure of FPS player performance, perhaps by breaking up FPS expertise into multiple skill – our system for evaluating opponent location awareness could conceivably be re-used for this purpose, to measure that particular skill.

Another limitation of our work is the narrow focus on utilizing the auditory awareness cues present in *Quake Live*. Simply put, other FPS games will require training players on a different set of cues. However, more importantly, designers should be focusing not so much on one skill versus another, but rather, on what the experts are doing that the novices aren't. The skills that fall under this category will change between different genres, or even between different games within a genre, however that novices are failing to master the skill experientially should be the criteria for scaffolding the skill. When novices are failing repeatedly but not learning, it's time to intervene.

On top of these core limitations and future work, there are additional paths that one might take from here. These other research directions include:

- *Scaffolding other skills present in multiplayer games.* We looked at scaffolding a single FPS skill, yet there are many skills in multiplayer games for which experiential learning is ineffective. Scaffolding may be used to introduce players to skills that can be learned independent of each other, such as aiming and navigation in FPS games [74], as well as skills that build upon existing ones, such as how strategic decision making and identifying threats [13] builds upon the utilization of auditory awareness cues.
- *Providing skill assistance to facilitate practice.* Our system was designed to assist players during the initial phases of skill acquisition; they still require practice in order to master

the skill. Based on Kiilis [37] game-based experiential learning theory, we may be able to provide skill assistance for the skill not being practiced to optimize the challenge level and maximize the time spent in the flow channel, where learning primarily occurs.

- *Determining the relationship between motivation to succeed or interest in the genre and the efficacy of scaffolding approaches.* Motivated players wishing to learn under their own volition might behave differently than those who complete the training simply because it is a paid experiment. In this work, we limited our characterization of players to their expertise; future work should incorporate additional characteristics of players and should validate our findings with players who are intrinsically motivated to learn the audio cues and improve their FPS skills.

CHAPTER 8

CONCLUSION

8.1 Summary

We set out to help players of different skill levels play together by scaffolding the weaker player to utilize a skill that experts are utilizing. That skill is the ability to locate opponents, and specifically, locating unseen opponents. To accomplish this, we first had to evaluate how well experts can accomplish this task, and work out the way in which they are able to do this.

In order to accomplish this, we designed and implemented a system to test how well participants of various skill levels were able to locate opponents under a variety of conditions. The system made use of hand-picked scenarios that were viewed as videos by the participant. Participants watched and responded to each video scenario, providing an estimation of the opponent's location and the information they used to make that estimate.

We found that the differences in how experts located opponents compared to novices occur in situations where only auditory information is present. Experts have learned how to easily make use of the information found in auditory awareness cues to locate opponents, whereas novices lacked confidence, did not understand the sound cues they were hearing, and were ultimately unable to locate the opponent. Hence, we focused on scaffolding novices to utilize the auditory awareness cues when locating opponents.

Since a utilization of the auditory cues are key to allowing experts to locate unseen opponents, the remainder of the work focused on this skill. To help novices learn to leverage the auditory cues, we introduced two prospective scaffolding approaches (HUD icons and external training) and tested how they changed the responses over the same set of scenarios. This was done by re-utilizing the custom system we had developed. The HUD icons were added to the videos and the training system was used before any video scenarios were presented.

We tested the efficacy of the training system separately, and found that that it was effective for learning the auditory cues. Participants had reached 96% accuracy by the end of the training. They also retained the cues well, with the performance decreasing only to 92%.

Both of our scaffolding approaches increased confidence, shifted the way that novices reported on an opponent's location to closer resemble the responses of experts, and improved accuracy. The training system emerged as being the superior scaffolding approach; in addition to the improvements that the HUD icons gave, training also helped novices identify more audio cues and further improved the accuracy of their responses.

8.2 Closing Thoughts

The current reliance on experiential learning within the multiplayer FPS genre has resulted in novices who may feel anxious and overwhelmed when they compete against tougher opponents [11], which could hinder their ability to learn the correct strategies to succeed [37]. Therefore, we investigated ways of scaffolding novices to develop a skill necessary for FPS success - that of locating opponents.

We showed that it is indeed possible to scaffold in-game skills utilized in multiplayer FPS games, and so our work takes a step towards helping people of disparate skill level play together in the long-term, by scaffolding novices to learn and use a strategy commonly employed by experts. Scaffolding skill development can ultimately open up social play opportunities for novices who would not otherwise be able to play with their more expert friends, helping people use games to stay connected with others.

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APPENDIX A

FORMS

A.1 Consent Form

FPS Player Location Awareness Study

Before proceeding, please read the following. You must give your consent to continue.

Title: Evaluating player location awareness in first-person shooters

Researcher(s): Colby Johanson, M.Sc. Student, Department of Computer Science, University of Saskatchewan, 306-966-2327, colby.johanson@usask.ca

Purpose(s) and Objective(s) of the Research: The purpose of this project is to understand how players of differing skill levels are able to learn the whereabouts of other players in an FPS game.

Procedures:

- In this study, you will be asked to complete a survey asking some questions about yourself and your experience level. Next, you will watch a series of videos. After each video, you will be asked a series of questions related to the video. Following the videos, you will be asked to complete an additional questionnaire, asking you questions relating to your experience.
- This study will take approximately between 15 and 30 minutes to complete.

Funded by: The Natural Sciences and Engineering Research Council of Canada (NSERC).

Potential Risks and Benefits: There are no known or anticipated risks to you by participating in this research. Your participation will help us to design games which aid novices in the learning of fundamental skills.

Confidentiality:

- Confidentiality will be maintained throughout the study. The entire process and data will be anonymized. Data will only be presented in the aggregate and any individual user comments will be anonymized prior to presentation in academic venues.
- Only the principal researcher and his research assistants will have access to the data to ensure that your confidentiality is protected.
- Storage of Data
 - Data (including survey and interview responses, logs of computer use, and videos of interaction) will be stored on a secure password-protected server for 7 years after data collection.
 - After 7 years, the data will be destroyed. Paper data will be shredded and digital data will be wiped from hard disks beyond any possibility for data recovery.

Right to Withdraw:

- Your participation is voluntary. You may withdraw from the research project for any reason, at any time without explanation.
- Should you wish to withdraw, you may do so at any point, and we will not use your data; we will destroy all records of your data.
- Your right to withdraw data from the study will apply until the data have been aggregated (one week after study completion). After this date, it is possible that some form of research dissemination will have already occurred and it may not be possible to withdraw your data

Follow up: To obtain results from the study, please contact Colby Johanson (colby.johanson@usask.ca).

Questions or Concerns:

- Contact the researcher(s) using the information at the top.
- This research project has been approved on ethical grounds by the University of Saskatchewan Research Ethics Board. Any questions regarding your rights as a participant may be addressed to that committee through the Research Ethics Office ethics.office@usask.ca (306) 966-2975. Out of town participants may call toll free (888) 966-2975.

Do you give your consent?

- ☐ I consent
- ☐ I do not consent

Continue